FOURTH EDITION

A
000 631 266
4
UC SOUTHERN REGIONAL LIBRARY FACILITY

ENGINEER'S FIELD BOOK.

FROST.

UCSB LIBRARY
X-62985

,75

John W. Donohue,
Springfield, Massachusetts.
June 10th 1895.

THE PROPERTY OF
John W. Donohue,
SPRINGFIELD, MASS.

ENGINEER'S

FIELD BOOK.

BY

C. S. CROSS, CIVIL ENGINEER.

TO WHICH ARE ADDED SEVEN CHAPTERS ON

RAILROAD LOCATION AND CONSTRUCTION.

COMPILED AND EDITED BY

GEO. H. FROST, C. E.

FOURTH EDITION.

NEW YORK:
ENGINEERING NEWS PUBLISHING CO.,
1893.

COPYRIGHT, 1893, BY
ENGINEERING NEWS PUBLISHING COMPANY.

CONTENTS.

CHAPTER I.

PAGES.

CROSS' ENGINEER'S FIELD BOOK.....5-44

Railroad Curves, 5. Radius and Degree of Curve, 6. Examples, 7. Deflection from Tangents, 8. Field Notes for a Two-degree Curve, 9. Field Notes for a Three-degree Curve, 11. Reverse Curves, 13. Compound Curves, 14. Formulas, 17. Railroad Curve Tables, 18-27. Table for Converting Minutes and Seconds to Decimals of a Degree, 28. Curve Table, 29-30. Field Notes of a Survey, 31. Prismoidal Formula, 32. Field Notes for Sections, 34. Computation of Earthwork, 35. Excavation and Embankment Tables, 37-43. Charles S. Cross, 44.

CHAPTER II.

SMITH'S ENGINEERING FIELD WORK.....45-64

Preliminary Organization of Field Party, 46. Care of Men, 47. The Transitman, 47. The Leveller, 49. The Head Chainman, 50. The Rear Chainman, 52. Location, 53. The Topographer, 54. Keeping Transit Notes, 55. Compound Curves, 58. Land Lines, 59. Preserving the Lines, 60. Centers and Grades, 61. Culverts and Masonry, 62. Earthwork Measurement, 62. Responsibility of an Engineer, 63.

CHAPTER III.

SHUNK'S REGULATIONS DURING CONSTRUCTION.....65-85

Organization, 65. Preparatory Work, 66. Right of Way, 68. Final Preparations for Construction, 69. Structure Plans, 70. Field and Office Records, 71. Inspectors and Timekeepers, 76. Estimates, 77. Accounts, Supplies and Sundries, 78. Miscellaneous Instructions and Suggestions, 79. Barnes' Instructions relative to Field Notes, 85.

CHAPTER IV.

TOPOGRAPHY AND STAKING-OUT PROBLEMS.....86-102

Table for Computing Right of Way Areas, 86. Topographical Field Work, 87. Method of Locating Contours, 87. Field Notes, 88. Field Plotting, 89. Locating Buildings, 89. Methods of Setting Slope Stakes, 90. I. For Level Sections, 90. II. For Irregular Sections, 90. III. With a Patent Tape, 92. IV. By Computation from Formulas, 93. Flattening a Curve, 94. Le Baron's Methods for Staking-out Switches, 95. Metric Railway Curves, 98.

CHAPTER V.

TRANSITION OR EASEMENT CURVES 103-117
The Tapering Curve, 103. The Railroad Spiral, 104. The Pennsylvania Method, 104. The Transition Spiral, 105. Spalding's Location of the Cubic Parabola, 106. Location by Ordinates, 107. Location by Deflection Angles, 109. Special Cases, 113. Table of Ordinates for Locating the Cubic Parabola, 114. Table of Deflections for Locating the Cubic Parabola, 115. Table for Corrections, 116. Elevation of the Outer Rail, 116.

CHAPTER VI.

EARTHWORK AND MASONRY 118-130
Fisher's Method of Estimating Overhaul in Earthwork, 118. 1. Compilation of Data, 119. 2. Plotting the Profile, 120. Taking off the Results, 121. Expansion of Rock in Embankment, 122. Specht's Notes on Earthwork, 122. Wellington's Rules for Earthwork Computation, 124. Levee Construction, 125. Specifications for Masonry, 126. Brick for Buildings and for Arches, 127. Rubble, 127. Squared Stone Masonry, 128. Ashlar Masonry, 129.

CHAPTER VII.

CULVERTS AND BRIDGES 131-145
Standard Timber Box Culverts, 131. Low's Formula and Tables for Maximum Spans of Box Culverts, 135. Specifications for Stone Box Culverts, 136. Specifications for Arch Culverts, 137. Howe Truss Bridges, 139. Cost of Labor in Framing and Erecting a Howe Truss Bridge, 143. Howe Trusses on Canadian Pacific Railway, 144. Formulas for the Weights of Bridges, 145.

CHAPTER VIII.

CONSTRUCTION DETAILS 146-159
Centers for Arches, 146. Repairs to the Arch of the Musconetcong Tunnel, 150. Standard Fences and Gates on Canadian Pacific Railway, 153. Substructure for a Water Tank, 154. A Pile Driving Machine, with two Plates, 155. Age of Railroads in Different Countries, 158. Rules for Measuring Work, 159. Directions for Making Drawings for Reproduction, 159.

APPENDIX.

BOOKS FOR RAILROAD ENGINEERS 160-165
Mathematics. Surveying. Drawing. Mechanics. Astronomy and Geodesy. Bridges and Roofs. Construction. Hydraulics.

THE PROPERTY OF
John W. Donohue,
SPRINGFIELD, MASS.

CHAPTER I.

Cross' Engineer's Field Book.

RAILROAD CURVES.

The following tables show the distance from the point of intersection of the tangent lines to the beginning of a one degree curve, the angle of deflection (=angle at centre) being known.

In the columns, under the head of degrees and opposite the minutes, are given the distances in feet from the intersection of tangents to the beginning of one degree curve.

To ascertain the distance for any given degree of curve, divide the distance given in the tables for a One degree curve, by the degrees of the required curve, and you have the distance from the point of intersection to the beginning or end of curve.

EXAMPLE:

Required the distance from the point of intersection of tangents to the beginning of a Two degrees curve, the angle of deflection being 25°.

In the tables under 25°, and opposite 0′, find 1270.28 which divided by the degrees of the curve (2°) give 635.14 feet the required distance.

In staking the centre line for a railroad or a canal, stakes should be driven down to near the surface of the ground, at the intersection of the tangents, and at the different stations; and nails set in indicating the centre point. These stakes serve also for leveling purposes and are useful in detecting errors while the work is being relevelled and staked out.

The beginning and end of curves should have reference stakes set at right angle to the centre line, similarly driven and marked, and at such convenient distance from the centre as will insure them from being displaced in making excavations and embankments; and at all the above named points another stake for numbering, &c., should be firmly driven adjacent to them.

The radius of a One degree curve is 5730 feet. The circle being divided into 360 parts of one degree (equal angle of deflection) give 360 chords of one foot in length at the circumference, and also a radius of 57.3 ft. thus:

$$\frac{360}{3.1416} = \frac{114.6}{2} = 57.3$$

The chord of	One foot	in length	for 1 degree			=	57.3 ft.	Radius.
"	10	feet	"	"	"	=	573.0	"
"	100	"	"	"	"	=	5730.0	"

Or the radius may be calculated by natural sines, thus:

sin. 1°: 100 ft. chord : : sin. 89° 30′ : 5730 ft. radius.

To determine the degree of curvature, having the radius given, divide the radius of a One degree curve, 5730, by the radius of the given curve.

EXAMPLE:

Required the degree of a curve having a radius of 1000 feet:

$$\tfrac{5730}{1000} = 5.73° = 5° \, 43' \, 48''$$

To determine the length of the curve having the angle of deflection given: divide the angle of deflection (=angle at centre) by the degrees of the curve, and you have the required length of the curve. If there are degrees and minutes in the angle of deflection, the minutes should be converted into decimals.

EXAMPLE:

The angle of deflection being 20° 49′, $\frac{49}{60} = 0.816$. Then 20.816 is the distance for a One degree curve; if for a 2 degrees curve, divide this result by 2; for a 3 degrees curve, divide by three, and so on.

The angle of deflection being given, the following results are readily determined:

Angle of deflection	Degree of curve	Deflection per 100 feet.	Radius of curve	Dist. from intersec. to beginning of curve.	Length of curve.
20° 49′	1°	0° 30′	5730.	1052.49	2081.6
20° 49′	2°	1° 00′	2865.	526.24	1040.8
20° 49′	3°	1° 30′	1910.	350.83	693.8
20° 49′	4°	2° 00′	1432.5	263.12	520.4
20° 49′	5°	2° 30′	1146.	210.50	416.3

To ascertain the radius of a curve, having the angle of deflection, and the distance from intersection to beginning of curve given. Find the distance for the angle of deflection in the tables, which divided by 5730. gives the natural tangent of half the angle.

Then divide the distance from intersection to beginning of curve by the natural tangent of half the angle, and you have the radius.

EXAMPLE:

Required the Radius of a curve, the angle of deflection being 20°, and the distance from intersection of tangents to beginning of curve 225 feet.

Under 20° and opposite 0′ in the tables, find 1010.37, which divided by 5730 feet gives the natural tangent 0.17633. Then 225 ft. divided by 0.17633 gives the radius 1276 feet.

FIELD NOTES FOR A ONE DEGREE CURVE.

Bearing of 1st tangent . . . . . N. 20° W.
" 2d. " . . . . . N. 40° W.
Angle of deflection by needle . . . . . 20°
" " " graduated card . . . 20°

The angles measured with the card are the most reliable; but the angles by the needle although it often indicates a slight differ-

ence, serves as a check to greater errors which may arise in reading the degrees on the graduated limb of the instrument.

* Station No. 506.2000 Intersection of tangents.

— 10.1037 from intersection to beginning of curve.

* Station No. 496.0963 point at which curve commences.

+ 20.0000 length of curve.

* Station No. 516.0963 point at which curve terminates.

DEFLECTION FROM TANGENTS.

Stations.	Length of chords in feet.	Deflection from tangent.	REMARKS.
496.096	" "	" "	* Beginning of curve.
497.	90.37	0° 27	1° to left. (Tang. due N.)
498.	100.00	0° 57	
499.	100.00	1° 27	
500.	100.00	1° 57	
501.	100.00	2° 27	
502.	100.00	2° 57	Change point.
503.	100.00	3° 27	
504.	100.00	3° 57	
505.	100.00	4° 27	
506.	100.00	4° 57	
507.	100.00	5° 27	
508.	100.00	5° 57	
509.	100.00	6° 27	* Change point.
510.	100.00	6° 57	
511.	100.00	7° 27	
512.	100.00	7° 57	
513.	100.00	8° 27	
514.	100.00	8° 57	
515.	100.00	9° 27	
516.	100.00	9° 57	
516.0963	9.63	10° 00	* End of curve. (Tangent N. 20° W.)

FIELD NOTES FOR A TWO DEGREES CURVE.

Bearing of 1st tangent..... N 10° W.
" 2d " ..... N 30° W.
Angle of deflection by needle..... .... 20°
" " by graduated card..... 20°
Station... 506.200 intersection of tangents.
— 5.052 from do. to beginning of curve.

Station.... 501.148 point at which the curve commences.
+ 10.000 length of the curve.

Station.... 511.148 point at which the curve terminates.

DEFLECTION FROM TANGENTS.

Stations.	Length of chords in feet.	Deflection from tangent.	REMARKS.
501.148	,, ,,	0° 00′	* Beginning of curve 2° to left.
502.	85.20	0° 51	(Tangent N 10° W.)
503.	100.00	1° 51	
504.	100.00	2° 51	
505.	100.00	3° 51	
506.	100.00	4° 51	
507.	100.00	5° 51	* Change point.
508.	100.00	6° 51	
509.	100.00	7° 51	
510.	100.00	8° 51	
511.	100.00	9° 51	
511.148	14.80	10° 00	* End of curve. (Tangent N 30° W.)

In curves of great length, the instrument should be moved forward in about every five or six hundred feet to insure accuracy, and often to avoid obstruction in line. The mode of proceeding in such cases may be illustrated with the deflections of the 2° curve.

The instrument in the first place is set at station 501.148 and the deflection from tangent to station 507 is 5° 51′. Now change the position of the instrument to station 507, and bring the cross hairs to bear on the staff at station 501.148; after clamping the instrument turn with the vernier as a test

for station 502,	0°51′	
for " 503,	1°51′	
for " 504,	2°51′	
for " 505,	3°51′	
and for the tangential station 507,	5°51′	* Ch. pt.

If the stakes are found to be correct, continue the setting of the remaining stakes to end of curve, and deflect the degrees from the beginning of curve given in the field notes opposite the respective stations.

When an odd number of minutes are to be turned off at the commencement and for each successive station, the inconvenience may be obviated by setting the vernier the number of minutes for the required chord in an opposite direction from that in which you would turn for the stations in the curve; or so that the instrument when set in line with the tangent and clamped, the nonius instead of reading 0, will indicate the number of degrees or minutes which would be deflected to strike in line with the first stake to be set in the curve. Then the remainder of the stations will be free from the odd minutes which would otherwise be turned off for each successive station.

When the instrument is moved forward to another station, the same mode may be adopted with reference to setting the nonius preparatory to bringing the cross hairs to bear on the staff at the beginning of curve.

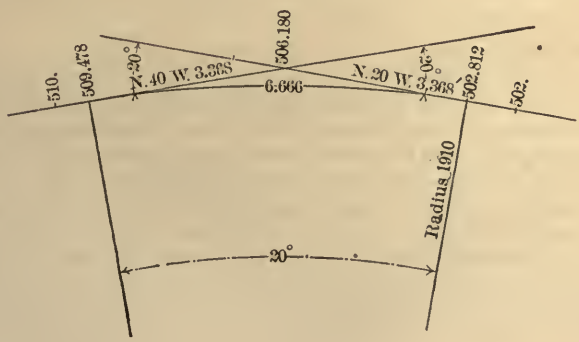
By determining the tangents at the various points in the curve over which the instrument may be set, the staking of the curve may be prosecuted with less liability to error.

At the end of curve the instrument should be set over the stake to ascertain if the tangent produced from deflection corresponds with the course and direction of the tangential line.

Field Notes and method of staking a 3° Curve.

Bearing of 1st tangent, N. 20° W.
" 2d " N. 40° W.
Angle of deflection by needle 20°.
" " by graduated card 20°.

* Station . .	506.180	intersection of tangents.	
	— 3.368	from do.	do. to beginning of curve.
* Station . .	502.812	point at which the curve commences.	
	+ 6.666	length of curve.	
* Station . .	509.478	point at which the curve terminates.	



The notes are put down as represented in this diagram, and numbered from right to left when curving to the left, and from left to right when curving to the right.

FIELD NOTES.

No. of Station	Length of chords.	Course of tangents and chords.	Deflect'n from tangent.	REMARKS.
502.812	" "	N 20° W	0° 0′	* B. C. 3° to left.
503.	18.8	20° 17′	0° 17′	
504.	100	22. 04	1. 47	
505.	100	25. 04	3. 17	* Change point.
506.	100	28. 04	4. 47	
507.	100	31. 04	6. 17	
508.	100	34. 04	7. 47	
509.	100	37 04	9. 17	
509.478	47.8	29. 04	10. 00	* E. C.
510.	52.2	N 40° 00 W		

The number at which the curve ends should be given to the chainman before proceeding to measurement, so that the proper signal may be made by him on arriving at the station next preceding the termination of the curve.

Then set the instrument over the point of curve at station 502.812 and deflect from the tangent line for station 503, 0° 17′
" " 504, 1° 47′
" " 505, 3° 17′

and so on to the end of curve as per column of deflection, unless the instrument is moved forward. If it is necessary to move the instrument, then set it over another stake in the curve, bring the cross hairs to bear on the staff at the beginning of curve and clamp the instrument; then turn off for the tangent at the station selected, the same number of degrees originally turned from tangent at beginning of curve in setting the stake, and 1° 30′ additional for each successive station of 100 feet as you advance; the angles should correspond with those given in the column of deflections set opposite the respective stations.

It frequently occurs that the instrument has to be changed to points intermediate between two stations.

If in a five degrees curve, for instance, it is necessary to change the instrument from station No. 0, there being an obstruction in

the line of sight between station 0 and station No. 3. and nothing to prevent the instrument being set over a point in the curve 30 feet distant from station 2; the deflections would be made as follows:

Station	0	Deflection	= 0° 00 B. C. 5° R.	
"	1	"	2° 30.	
"	2	"	5° 00.	
"	2.30	"	5° 45.	* Change point.

Then move the instrument forward, and set it over station 2.30, and bring the cross hairs to bear on the staff at the beginning of the curve, station 0; then turn off 5° 45′ for tangent at station 2.30 and 1° 45′ for 70 feet the remainder of station No. 3, making in all for station No 3—deflections 7° 30′

"	4	"	10° 00′	
"	5	"	15° 00′	E. C.

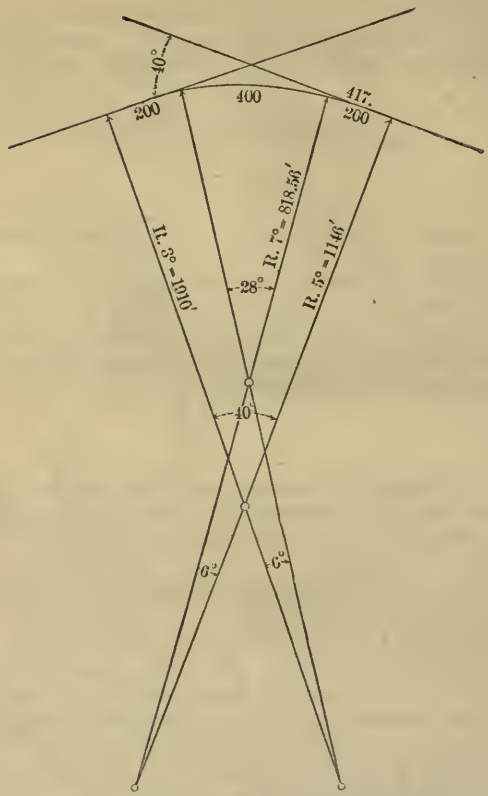
The angles for parts of a station on curves may be readily calculated and the angles turned off in such manner as will keep the stations of uniform length throughout the line.

REVERSE CURVES.

These may be put in according to the formation of the ground with equal radii, or not, as the case may require. In the latter case the degree of curve may be assumed and the curve continued as far as deemed necessary; and the tangent is then produced to the intersection and measured—and the angle of deflection determined. These give the data from which the radius and degree of curve are determined.—*See Pages* 6 *and* 7.

In the former case select a point in one of the tangents and turn from tangent such angle as the case may require, and measure on this line the distance between the tangents. Then set in a point one half of this distance for the point of reversion, from which both curves may be staked out.—*See Pages* 6 *and* 7.

If you wish to compound a curve so that the trains will pass less abruptly from tangent into and through the curve, it may be done in the following manner:



We will assume the angle of deflection to be 40°; in the tables under 40° and opposite 0′ find 2085.55, the distance from intersection of tangents to beginning of a one degree curve.

If you wish to lay out a compound equivalent to a curve of 5° for the whole angle, divide the distance found (2085.55) by 5, degree of the curve; and you have the point of beginning 417 ft. from intersection of tangents. You will then decide on what length to substitute the less degree of curve.

If a 3° curve is decided on, and the distance 200 feet at each end of the 5° curve, then deduct 3° for each station of 100 feet, making

12° from the total angle of deflection, (40°) and you have 28° to be divided equally between the stations of the intermediate curve, or $\frac{28}{4} = 7°$, the required degree of curve.

FIELD NOTES.

No. of Station.	Course of chords.	Deflection.	REMARKS.
No 0.	" "	0° 00′	Beginning of curve,
1	N 1° 30′ W	1° 30′	
2	4 30	3 00	End of curve, 3°, B. C. 7°
3	9 30	3 30	From tangent.
4	16 30	7 00	
5	28 30	10 30	
6	30 30	14 00	E. C. 7°, B. C. 3°.
7	35 30	1 30	From tangent.
8	38 30	3 00	E. C. 3°. Tangent, N 40° W.

NATURAL TANGENTS.

From the tables may also be determined the natural tangent for any given number of degrees and minutes from one degree to 45°, by taking the distance given in the tables for twice the angle of which the tangent is sought, and dividing the same by 5730.

EXAMPLES :

1st. Required the natural tangent of 30°. Under 60° (twice the angle) find in the tables 3308.21 and divide the same by 5730, and you have the natural tangent for 30° = 0.57735.

2d. Required the natural tangent for an angle of 7° 28′; in the

column of distances under 14° and opposite 56′ (twice the angle) find 750.97, which divided by 5730 give the natural tangent for 7° 28′ equal to 0.13106.

MEASUREMENT WITH GUNTER'S CHAIN.

When a 66 feet chain is used for the length of stations, the radius of a one degree curve, 5730 feet, may represent 57.30 chains of 66 feet, and the distances in the tables applied the same as for chains of 100 feet in length; but the radius as well as the length of stations will be proportionally less than for stations of 100 feet in length by $\frac{1}{34}$ part.

If a 66 feet chain is used, the distance after being found in the tables, may be divided by 66, and the stations in the curve reduced to 75.76 links which are equal to 50 feet, one half the length of the stations generally adopted in staking the center line of railroads; and the curve staked out accordingly, turning off one half the number of degrees required for the stations of 100 feet in length.

The degree of curvature is understood to express the number of degrees per 100 feet, and hence the convenience of making the stations of such length as will give a definite idea of the degree of curve and length of radius.

The following abbreviations are used by some Engineers.

P. C. For Point of Curve, or Beginning of Curve.

P. T. " " " Tangent, or End of Curve.

P. C. C. " " " Compound Curve—or end of one curve and beginning of another, curving in the same direction.

P. R. C. " " " Reverse Curve, or point where the direction of the curve is changed from right to left, or *vice versa.*

P. I. " " " Intersection of Tangents.

[Values of the radius corresponding to different degrees of curve are shown in the following table:

Degree.	Radius.	Degree.	Radius.	Degree.	Radius.
0° 30′	11459.2	6° 30′	881.95	13°	441.68
1	5729.6	7	819.02	14	410.27
1 30	3819.8	7 30	764.49	15	383.06
2	2864.9	8	716.78	16	359.27
2 30	2292.0	8 30	674.69	17	338.27
3	1910.1	9	637 27	18	319 62
3 30	1637.3	9 30	603.81	19	302.94
4	1432.7	10	573.69	20	287.94
4 30	1273.6	10 30	546.44	25	231.01
5	1146.3	11	521.67	30	193.18
5 30	1042.1	11 30	499.06	35	166.28
6	955.4	12	478.34	40	146.19

Let I be the angle of inclination between the two tangents, d the degree of the curve, R its radius, and T the distance from *P. I.* to *P. C.* or *P. T.* Then the following formulas may be used to give accurate results:

For the radius $$R = \frac{50}{\sin \frac{1}{2} d}$$

For the tangent distance $T = R \tan \frac{1}{2} I.$

These formulas will often be needed in the field for curves of over 6 degrees. For instance, when $I = 20°$ and $d = 10°$, the rule of page 6 gives $R = 573.0$ feet and page 20 gives $T = 101.04$ feet, while the accurate formulas give $R = 573.69$ feet and $T = 101.16$ feet. If d is assumed and I is given, the value of T may be found, without computing the radus, from the formula

$$T = 50 \frac{\tan \frac{1}{2} I}{\sin \frac{1}{2} d}$$

and this in general must be used in careful location, particularly whenever d is greater than five or six degrees.—THE EDITOR.]

RAILROAD CURVE TABLES.

′	0°	1°	2°	3°	4°	5°	6°	7°	8°	′
0	0.00	50.02	100.00	150.07	200.09	250.17	300.30	350.44	400.70	0
1	0.83	50.85	100.83	150.90	200.92	251.00	301.14	351.28	401.54	1
2	1.67	51.69	101.67	151.74	201.76	251.84	301.97	352.11	402.37	2
3	2.50	52.52	102.50	152.57	202.59	252.67	302.80	352.95	403.21	3
4	3.33	53.35	103.34	153.41	203.43	253.51	303.64	353.79	404.05	4
5	4.17	54.18	104.17	154.24	204.26	254.34	304.47	354.62	404.88	5
6	5.00	55.02	105.01	155.08	205.10	255.18	305.31	355.46	405.72	6
7	5.83	55.85	105.84	155.91	205.93	256.01	306.14	356.30	406.55	7
8	6.67	56.68	106.68	156.75	206.77	256.85	306.98	357.13	407.39	8
9	7.50	57.52	107.51	157.58	207.60	257.68	307.81	357.97	408.23	9
10	8.33	58.35	108.35	158.42	208.44	258.52	308.65	358.81	409.06	10
11	9.17	59.18	109.18	159.25	209.27	259.35	309.48	359.64	409.90	11
12	10.00	60.01	110.02	160.09	210.11	260.20	310.32	360.48	410.74	12
13	10.83	60.85	110.85	160.92	210.94	261.03	311.15	361.32	411.57	13
14	11.67	61.68	111.69	161.76	211.77	261.86	311.99	362.15	412.41	14
15	12.50	62.52	112.52	162.59	212.61	262.70	312.83	362.99	413.25	15
16	13.33	63.35	113.36	163.43	213.45	263.54	313.66	363.83	414.08	16
17	14.17	64.18	114.19	164.26	214.28	264.37	314.49	364.66	414.92	17
18	15.00	65.01	115.02	165.09	215.11	265.20	315.33	365.50	415.75	18
19	15.83	65.85	115.86	165.93	215.95	266.04	316.16	366.34	416.59	19
20	16.67	66.68	116.69	166.76	216.78	266.87	317.00	367.17	417.43	20
21	17.50	67.51	117.53	167.60	217.62	267.71	317.84	368.01	418.26	21
22	18.33	68.35	118.36	168.43	218.45	268.54	318.67	368.85	419.10	22
23	19.17	69.18	119.20	169.27	219.29	269.38	319.50	369.68	419.94	23
24	20.00	70.01	120.03	170.10	220.12	270.21	320.34	370.52	420.77	24
25	20.83	70.85	120.87	170.94	220.96	271.05	321.18	371.36	421.61	25
26	21.67	71.68	121.70	171.77	221.79	271.88	322.01	372.19	422.45	26
27	22.50	72.51	122.54	172.61	222.63	272.72	322.85	373.03	423.28	27
28	23.33	73.34	123.37	173.44	223.46	273.54	323.68	373.86	424.12	28
29	24.17	74.18	124.21	174.28	224.30	274.38	324.52	374.70	424.95	29
30	25 00	75.01	125.03	175.10	225.13	275.21	325.35	375 54	425.79	30
31	25.83	75.84	125.87	175.88	225.96	276.05	326.19	376.38	426.63	31
32	26.67	76.68	126.70	176.72	226.80	276.88	327.03	377.22	427.47	32
33	27.50	77.51	127.53	177.55	227.63	277.72	327.86	378.05	428.31	33
34	28.33	78.34	128.37	178.39	228 47	278.55	328.69	378.89	429.15	34
35	29.17	79.17	129.20	179.22	229.30	279.39	329.53	379.73	429.98	35
36	30.00	80.01	130.04	180.06	230.14	280.23	330.37	380.57	430.82	36
37	30.83	80.84	130.87	180.89	230.97	281.06	331.20	381.41	431.66	37
38	31.67	81.67	131.71	181.73	231.81	281.90	332.04	382.24	432.50	38
39	32.50	82.51	132.54	182.56	232.64	282.73	332.87	383.08	433.34	39
40	33.33	83.34	133.38	183.40	233.48	283.57	333.71	383.92	434.18	40
41	34.17	84.17	134.21	184.23	234.31	284.41	334.55	384.76	435.02	41
42	35.00	85.01	135.05	185.07	235.15	285.24	335.38	385.60	435.86	42
43	35.83	85.84	135.88	185.90	235.98	286.08	336.22	386.43	436.70	43
44	36.66	86.67	136.72	186.74	236.82	286.91	337.05	387.27	437.54	44
45	37.50	87.51	137.55	187.57	237.65	287.75	337.89	388.11	438.37	45
46	38.33	88.34	138.38	188.40	238.48	288.59	338.73	388.95	439.21	46
47	39.17	89.17	139.22	189.24	239.32	289.42	339.56	389.79	440.05	47
48	40.00	90.00	140.05	190.07	240.15	290.26	340.40	390.62	440.89	48
49	40.83	90.84	140.89	190.91	240.99	291.09	341.23	391.46	441.73	49
50	41.67	91.67	141 72	191.74	241.82	291.93	342.07	392.30	442.57	50
51	42.50	92.50	142.56	192.58	242.66	292.77	342.91	393.14	443.41	51
52	43.33	93.34	143.39	193.41	243.49	293.60	343.74	393.98	444.25	52
53	44.17	94.17	144.23	194.25	244.33	294.44	344.58	394.81	445.09	53
54	45.00	95.00	145.06	195.08	245.16	295.27	345.41	395.65	445.93	54
55	45.83	95.84	145.90	195.92	246.00	296.11	346.25	396.49	446.76	55
56	46.67	96.67	146.73	196.75	246.83	296.95	347.08	397.33	447.60	56
57	47.50	97.50	147.57	197.59	247.67	297.78	347.92	398.17	448.44	57
58	48.33	98.33	148.40	198.42	248.50	298.62	348.76	399.01	449.28	58
69	49.17	99.17	149.24	199.26	249.34	299.46	349.60	399.85	450.12	59

RAILROAD CURVE TABLES.

′	9°	10°	11°	12°	13°	14°	15°	16°	17°	′
0	450.95	501.32	551.74	602.22	652.87	703.53	754.35	805.29	856.35	0
1	451.79	502.16	552.58	603.06	653.71	704.38	755.20	806.14	857.20	1
2	452.63	503.00	553.42	603.91	654.56	705.23	756 05	806.99	858.05	2
3	453.47	503.84	554.26	604.75	655.40	706.07	756.89	807.84	858.90	3
4	454.31	504.68	555.10	605.60	656.25	706.92	757.74	808.64	859.76	4
5	455.14	505.52	555.94	606.44	657.09	707.77	758.59	809.54	860.61	5
6	455.98	506.36	556.78	607.28	657.93	708.62	759.44	810.39	861.46	6
7	456.82	507.20	557.62	608.13	658.78	709.47	760.29	811.24	862.31	7
8	457.66	508.04	558.46	608.97	659.62	710.31	761.13	812.09	863.16	8
9	458.50	508.88	559.30	609.82	660.47	711.16	761.98	812.94	864.01	9
10	459.34	509.72	560.14	610.66	661.31	712.01	762.83	813.79	864.87	10
11	460.18	510 56	560.98	611.50	662 15	712.86	763.68	814.64	865.72	11
12	461.02	511.40	561.82	612.35	663.00	713.71	764.53	815.49	866.57	12
13	461.86	512.24	562.66	613.19	663.84	714.55	765.37	816.34	867.42	13
14	462.70	513.08	563.50	614.04	664.69	715.40	766.22	817.19	868.27	14
15	463.53	513.92	564.34	614.88	665.53	716.25	767.07	818.04	869.12	15
16	464.37	514.76	565.18	615.72	666.37	717.10	767.92	818.89	869.98	16
17	465.21	515.60	566.02	616.57	667.22	717.95	768.77	819.74	870.83	17
18	466.05	516.44	566.86	617.41	668.06	718.79	769.61	820 59	871.68	18
19	466.89	517.28	567.70	618.26	668.91	719,64	770.46	821.44	872.53	19
20	467.73	518.12	568.54	619.10	669.75	720.49	771.31	822 29	873.38	20
21	468.57	518.96	569.38	619.94	670.59	721.35	772.16	823.14	874.23	21
22	469.41	519 80	570.22	620.79	671.44	722.20	773.01	823 99	875.09	22
23	470.25	520.64	571.06	621.63	672.28	723.04	773.85	824.84	875.94	23
24	471.08	521.48	571.90	622.48	673.13	723.89	774.70	825 69	876.79	24
25	471.92	522.32	572.74	623.32	673.97	724.74	775.55	826.54	877.64	25
26	472.76	523.16	573.58	624.16	674.81	725.59	776.40	827.39	878.49	26
27	473.60	524.01	574.42	625.01	675.66	726.44	777.35	828.24	879.34	27
28	474.43	524.85	575.27	625.85	676.51	727.28	778.09	829 09	880.20	28
29	475.26	525.69	576.11	626.70	677.35	728.13	778.94	829.94	881.05	29
30	476.10	526.53	576.95	627.55	678.20	728.97	779.79	830.79	881.90	30
31	476.94	527.37	577.79	628.39	679.04	729.82	780.64	831.64	882.75	31
32	477.78	528.21	578.63	629.24	679.89	730.66	781.49	832.49	883.61	32
33	478.62	529.05	579.48	630.08	680.73	731.51	782.34	833.35	884.46	33
34	479.46	529.89	580.32	630.93	681.58	732.35	783.19	834.20	885.32	34
35	480.30	530.73	581.16	631.77	682.42	733.20	784.04	835.05	886.17	35
36	481.14	531.57	582.00	632.61	683.26	734.05	784.89	835.90	887.02	36
37	481.99	532.41	582.84	633 46	684.11	734.89	785.74	836.75	887.88	37
38	482.83	533.25	583.69	634.30	684.95	735.74	786.59	837.61	888.73	38
39	483.67	534.09	584.53	635.15	685.80	736.58	787.44	838.46	889.59	39
40	484.51	534.93	585.37	635.99	686.64	737.43	788.29	839.31	890.44	40
41	485.35	535.77	586.21	636.83	687.48	738.28	789.14	840.16	891.29	41
42	486.19	536.61	587.05	637.68	688.33	739.12	789.99	841.01	892.15	42
43	487.03	537.45	587.90	638.52	689.17	739.97	790.84	841.87	893.00	43
44	487.87	538.29	588.74	639.37	690.02	740.81	791.69	842.72	893.86	44
45	488.71	539.13	589.58	640.21	690.86	741.66	792.54	843.57	894.71	45
46	489 56	539.97	590.42	641.05	691.70	742.51	793.39	844.42	895.56	46
47	490.40	540.81	591.26	641.90	692.55	743.35	794.24	845.27	896.42	47
48	491.24	541.65	592.11	642.74	693.39	744.20	795.09	846.13	897.27	48
49	492.08	542.49	592.95	643.59	694.24	745.04	795.94	846.98	898.13	49
50	492.92	543.33	593.79	644.43	695.08	745.89	796.79	847.83	898.98	50
51	493.76	544.17	594.63	645.27	695.92	746.74	797.64	848.68	899.83	51
52	494.60	545.01	595.47	646.12	696.77	747.58	798.49	849.53	900.69	52
53	495.44	545.85	596.32	646.96	697.61	748.43	799.34	850.39	901.54	53
54	496.28	546.69	597.16	647.81	698.46	749.27	800.19	851.24	902.40	54
55	497.12	547.53	598.00	648.65	699.30	750.12	801.04	852.09	903.25	55
56	497.96	548.37	598.84	649.49	700.14	750.97	801.89	852.94	904.10	56
57	498.81	549.21	599.68	650.34	700.99	751.81	802.74	853.79	904.96	57
58	499.65	550.06	600.53	651.18	701.83	752.66	803.59	854.65	905.81	58
59	500.48	550.90	601.38	652.03	702.68	753.50	804.44	855.50	906.67	59

RAILROAD CURVE TABLES.

′	18°	19°	20°	21°	22°	23°	24°	25°	26°	′
0	907.52	958.86	1010.37	1062.00	1113.80	1165.76	1217.96	1270.28	1322.88	0
1	908.38	959.72	1011.23	1062.86	1114.67	1166.63	1218.83	1271.16	1323.76	1
2	909.23	960.57	1012.09	1063.73	1115.53	1167.50	1219.70	1272.03	1324.63	2
3	910.09	961.43	1012.95	1064.59	1116.40	1168.37	1220.57	1272.91	1325.51	3
4	910.94	962.30	1013.81	1065.45	1117.26	1169.24	1221.45	1273.79	1326.39	4
5	911.80	963.15	1014.67	1066.32	1118.13	1170.11	1222.32	1274.66	1327.27	5
6	912.65	964.00	1015.53	1067.18	1118.99	1170.98	1223.19	1275.54	1328.14	6
7	913.51	964.86	1016.39	1068.04	1119.86	1171.85	1224.06	1276.42	1329.02	7
8	914.36	965.72	1017.24	1068.91	1120.72	1172.71	1224.93	1277.29	1329.90	8
9	915.22	966.58	1018.10	1069.77	1121.59	1173.58	1225.80	1278.17	1330.78	9
10	916.07	967.43	1018.96	1070.63	1122.45	1174.45	1226.67	1279.05	1331.65	10
11	916.93	968.29	1019.82	1071.50	1123.32	1175.32	1227.54	1279.92	1332.53	11
12	917.78	969.15	1020.68	1072.36	1124.18	1176.19	1228.42	1280.80	1333.41	12
13	918.64	970.00	1021.54	1073.22	1125.05	1177.06	1229.29	1281.69	1334.28	13
14	919.49	970.86	1022.40	1074.09	1125.91	1177.93	1230.16	1282.55	1335.16	14
15	920.35	971.72	1023.26	1074.95	1126.78	1178.80	1231.03	1283.43	1336.04	15
16	921.20	972.58	1024.12	1075.81	1127.64	1179.67	1231.90	1284.31	1336.92	16
17	922.06	973.43	1024.98	1076.68	1128.50	1180.54	1232.77	1285.18	1337.79	17
18	922.91	974.29	1025.84	1077.54	1129.37	1181.41	1233.64	1286.06	1338.67	18
19	923.77	975.15	1026.70	1078.40	1130.24	1182.28	1234.51	1286.94	1339.55	19
20	924.63	976.01	1027.56	1079.27	1131.10	1183.15	1235.39	1287.81	1340.43	20
21	925.48	976.86	1028.42	1080.13	1131.97	1184.02	1236.26	1288.69	1341.30	21
22	926.34	977.72	1029.27	1080.99	1132.83	1184.88	1237.13	1289.57	1342.18	22
23	927.19	978.58	1030.13	1081.86	1133.70	1185.75	1238.00	1290.44	1343.06	23
24	928.05	979.44	1030.99	1082.72	1134.56	1186.62	1238.87	1291.32	1343.94	24
25	928.90	980.29	1031.85	1083.58	1135.43	1187.49	1239.74	1292.20	1344.81	25
26	929.76	981.15	1032.71	1084.45	1136.29	1188.36	1240.61	1293.07	1345.69	26
27	930.61	982.01	1033.57	1085.31	1137.16	1189.23	1241.49	1293.95	1346.57	27
28	931.47	982.86	1034.43	1086.17	1138.02	1190.10	1242.36	1294.83	1347.44	28
29	932.32	983.72	1035.29	1087.04	1138.89	1190.97	1243.23	1295.70	1348.32	29
30	933.18	984.58	1036.15	1087.90	1139.75	1191.84	1244.10	1296.58	1349.20	30
31	934.04	985.44	1037.01	1088.76	1140.62	1192.71	1244.97	1297.46	1350.08	31
32	934.89	986.30	1037.87	1089.63	1141.48	1193.58	1245.85	1298.33	1350.96	32
33	935.75	987.16	1038.74	1090.49	1142.35	1194.45	1246.72	1299.21	1351.85	33
34	936.60	988.02	1039.60	1091.35	1143.22	1195.32	1247.59	1300.09	1352.73	34
35	937.46	988.88	1040.46	1092.22	1144.09	1196.19	1248.46	1300.96	1353.61	35
36	938.32	989.74	1041.32	1093.08	1144.95	1197.06	1249.34	1301.84	1354.49	36
37	939.17	990.60	1042.18	1093.94	1145.82	1197.93	1250.21	1302.72	1355.37	37
38	940.03	991.46	1043.05	1094.81	1146.69	1198.80	1251.08	1303.59	1356.25	38
39	940.88	992.32	1043.91	1095.67	1147.55	1199.68	1251.95	1304.47	1357.14	39
40	941.74	993.18	1044.77	1096.53	1148.42	1200.55	1252.83	1305.35	1358.02	40
41	942.60	994.04	1045.63	1097.40	1149.29	1201.42	1253.70	1306.22	1358.90	41
42	943.45	994.90	1046.49	1098.26	1150.15	1202.29	1254.57	1307.10	1359.78	42
43	944.31	995.76	1047.36	1099.12	1151.02	1203.16	1255.44	1307.98	1360.66	43
44	945.16	996.62	1048.22	1099.99	1151.89	1204.03	1256.32	1308.85	1361.54	44
45	946.02	997.48	1049.08	1100.85	1152.76	1204.90	1257.19	1309.73	1362.43	45
46	946.88	998.34	1049.94	1101.71	1153.62	1205.77	1258.06	1310.61	1363.31	46
47	947.73	999.19	1050.80	1102.58	1154.49	1206.64	1258.93	1311.48	1364.19	47
48	948.59	1000.95	1051.67	1103.44	1155.36	1207.51	1259.81	1312.36	1365 07	48
49	949.44	1000.91	1052.53	1104.30	1156.22	1208.38	1260.68	1313.24	1365.95	49
50	950.30	1001.77	1053.39	1105.17	1157.09	1209.25	1261.55	1314.11	1366.83	50
51	951.16	1002.63	1054.25	1106.03	1157.96	1210.12	1262.42	1314.99	1367.72	51
52	952.01	1003.49	1055.11	1106.89	1158.82	1210.99	1263.30	1315.87	1368.60	52
53	952.87	1004.35	1055.98	1107.76	1159.69	1211.86	1264.17	1316.74	1369.48	53
54	953.72	1005.21	1056.84	1108.62	1160.56	1212.73	1265.04	1317.62	1370.36	54
55	954.58	1006.07	1057.70	1109.48	1161.43	1213.61	1265.92	1318.50	1371.24	55
56	955.44	1006.93	1058.56	1110.35	1162.29	1214.48	1266.79	1319.37	1372.12	56
57	956.29	1007.79	1059.42	1111.21	1163.16	1215.35	1267.66	1320.25	1373.01	57
58	957.15	1008.65	1060.28	1112.07	1164.03	1216.22	1268.53	1321.13	1373.89	58
59	958.00	1009.51	1061.14	1112.94	1164.89	1217.09	1269.41	1322.00	1374.77	59

RAILROAD CURVE TABLES.

′	27°	28°	29°	30°	31°	32°	33°	34°	35°	′
0	1375.65	1428.65	1481.89	1535.30	1589.04	1643.08	1697.28	1751.83	1806.67	0
1	1376.53	1429.54	1482.78	1536.20	1589.94	1643.98	1698.19	1752.74	1807.59	1
2	1377.41	1430.42	1483.67	1537.09	1590.84	1644.88	1699.10	1753.66	1808.50	2
3	1378.30	1431.31	1484.56	1537.99	1591.74	1645.78	1700.01	1754.57	1809.42	3
4	1379.18	1432.20	1485.45	1538.88	1592.64	1646.69	1700.92	1755.48	1810.34	4
5	1380.06	1433.08	1486.34	1539.78	1593.54	1647.59	1701.83	1756.40	1811.25	5
6	1380.94	1433.97	1487.23	1540.67	1594.44	1648.49	1702.74	1757.31	1812.17	6
7	1381.82	1434.86	1488.12	1541.57	1595.34	1649.39	1703.65	1758.22	1813.09	7
8	1382.70	1435.74	1489.01	1542.47	1596.24	1650.29	1704.55	1759.13	1814.00	8
9	1383.59	1436.63	1489.90	1543.36	1597.14	1651.19	1705.46	1760.05	1814.92	9
10	1384.47	1437.52	1490.79	1544.26	1598.04	1652.09	1706.37	1760.96	1815.84	10
11	1385.35	1438.40	1491.68	1545.15	1598.94	1652.99	1707.28	1761.87	1816.75	11
12	1386.23	1439.29	1492.57	1546.05	1599.84	1653.90	1708.19	1762.79	1817.67	12
13	1387.11	1440.18	1493.46	1546.94	1600.74	1654.80	1709.10	1763.70	1818.59	13
14	1387.99	1441.06	1494.35	1547.84	1601.64	1655.70	1710.01	1764.61	1819.50	14
15	1388.88	1441.95	1495.24	1548.74	1602.54	1656.60	1710.92	1765.53	1820.42	15
16	1389.76	1442.84	1496.13	1549.63	1603.44	1657.50	1711.83	1766.44	1821 34	16
17	1390.64	1443.72	1497.02	1550.53	1604.33	1658.40	1712.74	1767.35	1822.25	17
18	1391.52	1444.61	1497.91	1551.42	1605.23	1659.30	1713.65	1768.26	1823.17	18
19	1392.40	1445.50	1498.80	1552.32	1606.13	1660.20	1714.56	1769.18	1824.09	19
20	1393.28	1446.38	1499.69	1553.21	1607.03	1661 11	1715.47	1770.09	1825.00	20
21	1394.17	1447.27	1500.58	1554.11	1607.93	1662.01	1716.38	1771.00	1825.92	21
22	1395.05	1448.16	1501.47	1555.00	1608.83	1662.91	1717.28	1771.92	1826.84	22
23	1395.93	1449.04	1502.36	1555.90	1609.73	1663.81	1718.19	1772.83	1827.75	23
24	1396.81	1449.93	1503.25	1556.80	1610.63	1664.71	1719.10	1773.74	1828.67	24
25	1397.69	1450.82	1504.14	1557.69	1611.53	1665.61	1720.01	1774.66	1829.59	25
26	1398.57	1451.70	1505.03	1558.59	1612.43	1666.51	1720.92	1775.57	1830.50	26
27	1399.46	1452.59	1505.92	1559.48	1613.33	1667.42	1721.83	1776.48	1831.42	27
28	1400.34	1453.48	1506.81	1560.38	1614.23	1668.32	1722.74	1777.39	1832.34	28
29	1401.22	1454 36	1507.70	1561.28	1615.13	1669.22	1723.65	1778.31	1833.25	29
30	1402.10	1455.25	1508.59	1562.17	1616.03	1670.12	1724.56	1779.22	1834.17	30
31	1402.99	1456.14	1509.48	1563.07	1616.93	1671.03	1725.47	1780.14	1835.09	31
32	1403.87	1457.03	1510.37	1563.96	1617.83	1671.93	1726.38	1781.05	1836.01	32
33	1404.76	1457.91	1511.26	1564.86	1618.74	1672.84	1727.29	1781.97	1836.93	33
34	1405.64	1458.80	1512.15	1565.75	1619.64	1673.74	1728.20	1782.88	1837.85	34
35	1406.53	1459.69	1513.04	1566.65	1620.54	1674.65	1729.10	1783.80	1838.77	35
36	1407.41	1460.58	1513.93	1567.54	1621.44	1675.55	1730.01	1784.71	1839.69	36
37	1408.30	1461.47	1514.82	1568.44	1622.34	1676.46	1730.92	1785.63	1840.61	37
38	1409.18	1462.35	1515.71	1569.34	1623.24	1677.36	1731.83	1786.54	1841.54	38
39	1410.07	1463.24	1516.60	1570.23	1624.15	1678.27	1732.74	1787.46	1842.46	39
40	1410.95	1464.13	1517.49	1571.13	1625.05	1679.17	1733.65	1788.37	1843.38	40
41	1411.84	1465.02	1518.38	1572.02	1625.95	1680.08	1734.56	1789.29	1844.30	41
42	1412.72	1465.91	1519.27	1572.92	1626.85	1680.98	1735.47	1790.20	1845.22	42
43	1413.61	1466.79	1520.16	1573.81	1627.75	1681.89	1736.38	1791.12	1846.14	43
44	1414.49	1467.68	1521.05	1574.71	1628.65	1682.79	1737.29	1792.03	1847.06	44
45	1415.38	1468.57	1521.94	1575.61	1629.56	1683.70	1738.20	1792.95	1847.98	45
46	1416.26	1469.46	1522.83	1576.50	1630.46	1684.61	1739.10	1793.86	1848.90	46
47	1417.15	1470.35	1523.73	1577.40	1631.36	1685.51	1740.01	1794.78	1849.82	47
48	1418.03	1471.23	1524.62	1578.29	1632.26	1686.42	1740.92	1795.69	1850.74	48
49	1418.92	1472.12	1525.51	1579.19	1633.16	1687.32	1741.83	1796.61	1851.66	49
50	1419.80	1473.01	1526.40	1580.08	1634.06	1688.23	1742.74	1797.52	1852.58	50
51	1420.69	1473.90	1527.29	1580.98	1634.97	1689.13	1743.65	1798.44	1853 50	51
52	1421.57	1474.79	1528.18	1581.88	1635.87	1690.04	1744.56	1799.35	1854.43	52
53	1422.46	1475.67	1529.07	1582.77	1636.77	1690.94	1745.47	1800.27	1855.35	53
54	1423.34	1476.56	1529.96	1583.67	1637.67	1691.85	1746.38	1801.18	1856.27	54
55	1424.23	1477.45	1530.85	1584.56	1638.57	1692.75	1747.29	1802.10	1857.19	55
56	1425.11	1478.34	1531.74	1585.46	1639.47	1693.66	1748.19	1803.01	1858.11	56
57	1425.99	1479.23	1532.63	1586.35	1640.38	1694.56	1749.10	1803.93	1859.03	57
58	1426.88	1480.11	1533.52	1587.25	1641.28	1695.47	1750.01	1804.84	1859.95	58
59	1427.77	1481.00	1534.41	1588.15	1642 18	1696.37	1750.92	1805.76	1860.87	59

RAILROAD CURVE TABLES.

′	36°	37°	38°	39°	40°	41°	42°	43°	44°	′
0	1861.79	1917.26	1973.01	2029.11	2085.55	2142.33	2199.52	2257.10	2315.09	0
1	1862.71	1918.19	1973.94	2030.05	2086.50	2143.28	2200.48	2258.06	2316.06	1
2	1863.64	1919.11	1974.88	2030.99	2087.44	2144.24	2201.44	2259.03	2317.03	2
3	1864.56	1920.04	1975.81	2031.93	2088.39	2145.19	2202.40	2259.99	2318.00	3
4	1865.48	1920.97	1976.75	2032.87	2089.33	2146.14	2203.35	2260.96	2318.97	4
5	1866.41	1921.89	1977.68	2033.81	2090.28	2147.10	2204.31	2261.92	2319.94	5
6	1867.33	1922.82	1978.61	2034.75	2091.22	2148.05	2205.27	2262.89	2320.91	6
7	1868.25	1923.74	1979.55	2035.69	2092.17	2149.00	2206.23	2263.85	2321.88	7
8	1869.17	1924.67	1980.48	2036.63	2093.11	2149.95	2207.19	2264.82	2322.85	8
9	1870.10	1925.60	1981.42	2037.67	2094.06	2150.91	2208.15	2265.78	2323.82	9
10	1871.02	1926.52	1982.35	2038.51	2095.00	2151.86	2209.11	2266.75	2324.79	10
11	1871.94	1927.45	1983.28	2039.45	2095.95	2152.81	2210.07	2267.71	2325.76	11
12	1872.86	1928.38	1984.22	2040.39	2096.89	2153.77	2211.02	2268.68	2326.73	12
13	1873.78	1929.30	1985.15	2041.33	2097.84	2154.72	2211.98	2269.64	2327.70	13
14	1874.71	1930.23	1986.09	2042.27	2098.78	2155.67	2212.94	2270.61	3328.67	14
15	1875.63	1931.15	1987.02	2043.21	2099.73	2156.63	2213.90	2271.57	2329.64	15
16	1876.55	1932.08	1987.95	2044.15	2100.67	2157.58	2214.86	2272.54	2330.61	16
17	1877.48	1933.01	1988.89	2045.08	2101.62	2158 53	2215.82	2273.50	2331.59	17
18	1878.40	1933.93	1989.82	2046.02	2102.57	2159.48	2216.78	2274.46	2332.56	18
19	1879.32	1934.86	1990.76	2046.96	2103.51	2160.44	2217.74	2275.43	2333.52	19
20	1880.24	1935.79	1991.69	2047.90	2104.46	2161.39	2218.69	2276.39	2334.49	20
21	1881.16	1936.71	1992.62	2048.84	2105.40	2162.34	2219.65	2277.36	2335.46	21
22	1882.09	1937.64	1993.56	2049.78	2106.35	2163.30	2220.61	2278.32	2336.44	22
23	1883.01	1938.56	1994.49	2050.72	2107.29	2164.25	2221.57	2279.29	2337.41	23
24	1883.93	1939.49	1995.43	2051.66	2108.24	2165.20	2222.53	2280.25	2338.38	24
25	1884.86	1940.42	1996.36	2052.60	2109.18	2166.16	2223.49	2281 22	2339.35	25
26	1885.78	1941.34	1997.29	2053.54	2110.13	2167.11	2224.45	2282.18	2340.32	26
27	1886.71	1942.27	1998.23	2054.48	2111.07	2168.06	2225.40	2283.15	2341.29	27
28	1887.63	1943.20	1999.16	2055.42	2112.02	2169.01	2226.36	2284.11	2342.26	28
29	1888.55	1944.12	2000.10	2056.36	2112.96	2169.97	2227.32	2285.08	2343.23	29
30	1889.47	1945.05	2001.03	2057.30	2113.91	2170.92	2228.28	2286.04	2344.20	30
31	1890.40	1945.98	2001.97	2058.24	2114.86	2171.87	2229.24	2287.01	2345.17	31
32	1891.32	1946.91	2002.90	2059.18	2115.80	2172.83	2230.20	2287.98	2346.15	32
33	1892.25	1947.85	2003.84	2060.13	2116.75	2173.78	2231.16	2288.94	2347.12	33
34	1893.17	1948.78	2004.77	2061.07	2117.70	2174.73	2232.12	2289.91	2348.10	34
35	1894.10	1949.71	2005.71	2062.01	2118.65	2175 69	2233 08	2290.88	2349 07	35
36	1895.03	1950.64	2006.65	2062.95	2119.59	2176.64	2234.04	2291.85	2350.04	36
37	1895.95	1951.57	2007.58	2063.89	2120.54	2177.59	2235 00	2292.82	2351.02	37
38	1896.88	1952.51	2008.52	2064.83	2121.49	2178.55	2235.97	2293.79	2351.99	38
39	1897.81	1953.44	2009.45	2065.78	2122.44	2179.50	2236.93	2294.75	2352.97	39
40	1898.73	1954.37	2010.39	2066.72	2123.38	2180.45	2237.89	2295.72	2353.94	40
41	1899.66	1955.30	2011.33	2067.66	2124.33	2181.41	2238.85	2296.69	2354.91	41
42	1900.59	1956.23	2012.26	2068.60	2125.28	2182.36	2239.81	2297.66	2355.89	42
43	1901.51	1957.17	2013.20	2069.54	2126.22	2183.31	2240 77	2298.63	2356 86	43
44	1902.44	1958.10	2014.34	2070.48	2127.17	2184.27	2241.73	2299.60	2357.84	44
45	1903.36	1959.03	2015.07	2071.43	2128.12	2185.22	2242.69	2300 56	2358.81	45
46	1904.29	1959.96	2016.01	2072.37	2129.07	2186.17	2243.65	2301.53	2359.78	46
47	1905.22	1960.89	2016.94	2073.31	2130.01	2187.13	2244 61	2302.50	2360 76	47
48	1906.14	1961.83	2017.88	2074.25	2130.96	2188 08	2245.57	2303 47	2361.73	48
49	1907.07	1962.76	2018.81	2075.19	2131.91	2189.03	2246.53	2304.44	2362.71	49
50	1908.00	1963.69	2019.75	2076.13	2132.86	2189.99	2247.49	2305.41	2363.68	50
51	1908.92	1964.62	2020.69	2077.08	2133.80	2190.94	2248 45	2306.37	2364.65	51
52	1909.85	1965.55	2021.62	2078.02	2134.75	2191.89	2249 42	2307.34	2365 63	52
53	1910.77	1966.49	2022.56	2078.99	2135.70	2192.85	2250.38	2308 31	23 6 60	53
54	1911.70	1967.42	2023.49	2079.90	2136.65	2193 80	2251.34	2309.28	2367.58	54
55	1912.63	1968.35	2024.43	2080.84	2137.59	2194.75	2252.30	2310.25	2368.55	55
56	1913.55	1969.28	2025.37	2081.78	2138.54	2195.71	2253.26	2311.22	2369.52	56
57	1914.48	1970.21	2026.30	2082.73	2139.49	2196 66	2254.22	2312.18	2370.50	57
58	1915.41	1971.15	2027.24	2083.67	2140.43	2197.61	2255.18	2313.15	2371.47	58
59	1916.33	1972.08	2028.17	2084.61	2141.38	2198.57	2256.14	2314.21	2372.45	59

RAILROAD CURVE TABLES.

′	45°	46°	47°	48°	49°	50°	51°	52°	53°	′
0	2373.42	2432.21	2491.46	2551.11	2611.27	2671.90	2733.04	2794.69	2856.86	0
1	2374.40	2433.20	2492.45	2552.11	2612.28	2672.92	2734.07	2795.72	2857.90	1
2	2375.38	2434.18	2493.45	2553.11	2613.29	2673.94	2735.09	2796.76	2858.95	2
3	2376.35	2435.17	2494.44	2554.11	2614.30	2674.95	2736.12	2797.79	2859.99	3
4	2377.33	2436.15	2495.43	2555.11	2615.31	2675.97	2737.14	2798.82	2861.03	4
5	2378.31	2437.14	2496.43	2556.11	2616.32	2676.99	2738.17	2799.86	2862.08	5
6	2379.29	2438.12	2497.42	2557.12	2617.32	2678.01	2739.19	2800.89	2863.12	6
7	2380.27	2439.11	2498.41	2558.12	2618.33	2679.03	2740.22	2801.92	2864.16	7
8	2381.24	2440.10	2469.40	2559.12	2619.34	2680.04	2741.25	2802.96	2865.20	8
9	2382.22	2441.08	2500.40	2560.12	2620.35	2681.06	2742.27	2803.99	2866.25	9
10	2383.20	2442.07	2501.39	2561.12	2621.36	2682.08	2743.30	2805.02	2867.29	10
11	2384.18	2443.05	2502.38	2562.12	2622.36	2683.10	2744.32	2806.06	2868.33	11
12	2385.16	2444.04	2503.38	2563.12	2623.37	2684.12	2745.35	2807.09	2869.38	12
13	2386.13	2445.02	2504.37	2564.12	2624.38	2685.13	2746.37	2808.12	2870.42	13
14	2387.11	2446.01	2505.36	2565.12	2625.39	2686.15	2747.40	2809.16	2871.46	14
15	2388.09	2447.00	2506.36	2566.12	2626.40	2687.17	2748.43	2810.19	2872.51	15
16	2389.07	2447.98	2507.35	2567.13	2627.41	2688.19	2749.45	2811.22	2873.55	16
17	2390.05	2448.97	2508.34	2568.13	2628.41	2689.21	2750.48	2812.26	2874.59	17
18	2391.02	2449.95	2509.33	2569.13	2629.42	2690.22	2751.50	2813.29	2875.63	18
19	2392.00	2450.94	2510.33	2570.13	2630.43	2691.24	2752.53	2814.32	2876.68	19
20	2392.98	2451.92	2511.32	2571.13	2631.44	2692.26	2753.55	2815.36	2877.72	20
21	2393.96	2452.91	2512.32	2572.13	2632.45	2693.28	2754.58	2816.39	2878.76	21
22	2394.94	2453.89	2513.31	2573.13	2633.46	2694.30	2755.61	2817.42	2879.81	22
23	2395.91	2454.88	2514.30	2574.13	2634.47	2695.31	2756.63	2818.46	2880.85	23
24	2396.89	2455.87	2515.30	2575.13	2635.48	2696.33	2757.66	2819.49	2881.89	24
25	2397.87	2456.85	2516.29	2576.13	2636.49	2697.35	2758.68	2820.52	2882.94	25
26	2398.85	2457.84	2517.28	2577.13	2637.50	2698.37	2759.71	2821.56	2883.98	26
27	2399.83	2458.82	2518.27	2578.13	2638.50	2699.39	2760.73	2822.59	2885.02	27
28	2400.80	2459.81	2519.27	2579.13	2639.51	2700.40	2761.76	2823.62	2886.06	28
29	2401.78	2460.80	2520.26	2580.13	2640.52	2701.42	2762.79	2824.66	2887.11	29
30	2402.76	2461.78	2521.25	2581.13	2641.53	2702.44	2763.81	2825.69	2888.15	30
31	2403.74	2462.77	2522.25	2582.13	2642.54	2703.46	2764.84	2826.73	2889.20	31
32	2404.72	2463.76	2523.24	2583.14	2643.55	2704.48	2765.87	2827.77	2890.24	32
33	2405.71	2464.75	2524.24	2584.14	2644.57	2705.50	2766.90	2828.81	2891.29	33
34	2406.69	2465.74	2525.23	2585.15	2645.58	2706.52	2767.93	2829.85	2892.34	34
35	2407.67	2466.73	2526.23	2586.15	2646.59	2707.54	2768.96	2830.89	2893.39	35
36	2408.65	2467.72	2527.22	2587.16	2647.60	2708.56	2769.99	2831.92	2894.43	36
37	2409.63	2468.71	2528.22	2588.16	2648.62	2709.58	2771.02	2832.96	2895.48	37
38	2410.61	2469.69	2529.21	2589.17	2649.63	2710.60	2772.04	2834.00	2896.53	38
39	2411.60	2470.68	2530.21	2590.17	2650.64	2711.62	2773.07	2835.04	2897.57	39
40	2412.58	2471.67	2531.20	2591.18	2651.65	2712.64	2774.10	2836.08	2898.62	40
41	2413.56	2472.66	2532.20	2592.18	2652.67	2713.66	2775.13	2837.12	2899.67	41
42	2414.54	2473.65	2533.19	2593.18	2653.68	2714.68	2776.16	2838.16	2900.71	42
43	2415.52	2474.64	2534.19	2594.19	2654.69	2715.70	2777.19	2839.20	2901.76	43
44	2416.50	2475.63	2535.18	2595.19	2655.70	2716.72	2778.22	2840.24	2902.81	44
45	2417.49	2476.62	2536.18	2596.20	2656.71	2717.74	2779.25	2841.28	2903.86	45
46	2418.47	2477.61	2537.17	2597.20	2657.73	2718.76	2780.28	2842.31	2904.90	46
47	2419.45	2478.60	2538.17	2598.21	2658.74	2719.78	2781.31	2843.35	2905.95	47
48	2420.43	2479.59	2539.17	2599.21	2659.75	2720.80	2782.34	2844.39	2907.00	48
49	2421.41	2480.58	2540.16	2600.22	2660.76	2721.82	2783.37	2845.43	2908.04	49
50	2422.39	2481.57	2541.16	2601.22	2661.78	2722.84	2784.40	2846.47	2909.09	50
51	2423.38	2482.56	2542.15	2602.23	2662.79	2723.86	2785.43	2847.51	2910.14	51
52	2424.36	2483.54	2543.15	2603.23	2663.80	2724.88	2786.45	2848.55	2911.18	52
53	2425.34	2484.53	2544.14	2604.24	2664.81	2725.90	2787.48	2849.59	2912.23	53
54	2426.32	2485.52	2545.14	2605.24	2665.83	2726.92	2788.51	2850.63	2913.28	54
55	2427.30	2486.51	2546.13	2606.24	2666.84	2727.94	2789.54	2851.67	2914.32	55
56	2428.28	2487.50	2547.13	2607.25	2667.85	2728.96	2790.57	2852.70	2915.36	56
57	2429.27	2488.49	2548.12	2608.25	2668.86	2729.98	2791.60	2853.74	2916.41	57
58	2430.25	2489.48	2549.12	2609.26	2669.87	2731.00	2792.63	2854.78	2917.46	58
59	2431.23	2490.47	2550.11	2610.26	2670.89	2732.02	2793.66	2855.82	2918.50	59

RAILROAD CURVE TABLES.

′	54°	55°	56°	57°	58°	59°	60°	61°	62°	′
0	2919.55	2982.81	3046.64	3111.10	3176.14	3241.86	3308.21	3375.20	3442.93	0
1	2920.60	2983.87	3047.71	3112.18	3177.23	3242.96	3309.32	3376.33	3444.07	1
2	2921.65	2984.93	3048.78	3113.26	3178.32	3244.06	3310.44	3377.45	3445.20	2
3	2922.71	2986.00	3049.86	3114.34	3179.42	3245.17	3311.55	3378.58	3446.34	3
4	2923.76	2987.06	3050.93	3115.42	3180.51	3246.27	3312.67	3379.70	3447.48	4
5	2924.81	2988.12	3052.00	3116.51	3181.60	3247.37	3313.78	3380.83	3448.61	5
6	2925.86	2989.18	3053.07	3117.59	3182.69	3248.47	3314.89	3381.95	3449.75	6
7	2926.92	2990.24	3054.14	3118.67	3183.79	3249.57	3316.01	3383.08	3450.88	7
8	2927.97	2991.31	3055.21	3119.75	3184.88	3250.68	3317.12	3384.20	3452.02	8
9	2929.02	2992.37	3056.29	3120.83	3185.97	3251.78	3318.24	3385.33	3453.16	9
10	2930.07	2993.43	3057.36	3121.91	3187.06	3252.88	3319.35	3386.45	3454.29	10
11	2931.13	2994.49	3058.43	3122.99	3188.16	3253.98	3320.46	3387.58	3455.43	11
12	2932.18	2995.55	3059.50	3124.07	3189.25	3255.08	3321.58	3388.70	3456.57	12
13	2933.23	2996.62	3060.57	3125.15	3190.34	3256.19	3322.69	3389.83	3457.70	13
14	2934.28	2997.68	3061.64	3126.23	3191.43	3257.29	3323.80	3390.95	3458.84	14
15	2935.33	2998.74	3062.72	3127.32	3192.52	3258.39	3324.92	3392.08	3459.97	15
16	2936.39	2999.80	3063.79	3128.40	3193.62	3259.49	3326.03	3393.20	3461.11	16
17	2937.44	3000.86	3064.86	3129.48	3194.71	3260.59	3327.15	3394.33	3462.25	17
18	2938.49	3001.93	3065.93	3130.56	3195.80	3261.70	3328.26	3395.45	3463.38	18
19	2939.54	3002.99	3067.00	3131.64	3196.89	3262.80	3329.36	3396.58	3464.52	19
20	2940.60	3004.05	3068.07	3132.72	3197.99	3263.90	3330.49	3397.70	3465.66	20
21	2941.65	3005.11	3069.15	3133.80	3199.08	3265.00	3331.60	3398.83	3466.79	21
22	2942.70	3006.17	3070.22	3134.88	3200.17	3266.10	3332.71	3399.95	3467.93	22
23	2943.75	3007.24	3071.29	3135.96	3201.26	3267.21	3333.83	3401.08	3469.07	23
24	2944.81	3008.30	3072.36	3137.04	3202.36	3268.31	3334.94	3402.20	3470.20	24
25	2945.86	3009.36	3073.43	3138.13	3203.45	3269.41	3336.05	3403.33	3471.34	25
26	2946.91	3010.42	3074.50	3139.21	3204.54	3270.51	3337.17	3404.45	3472.47	26
27	2947.96	3011.48	3075.58	3140.29	3205.63	3271.61	3338.28	3405.58	3473.61	27
28	2949.01	3012.55	3076.65	3141.37	3206.73	3272.72	3339.40	3406.70	3474.75	28
29	2950.07	3013.61	3077.72	3142.45	3207.82	3273.82	3340.51	3407.83	3475.88	29
30	2951.12	3014.67	3078.79	3143.53	3208.91	3274.92	3341.62	3408.95	3477.02	30
31	2952.18	3015.74	3079.87	3144.62	3210.01	3276.03	3342.74	3410.08	3478.16	31
32	2953.23	3016.80	3080.94	3145.70	3211.11	3277.14	3343.86	3411.22	3479.31	32
33	2954.29	3017.87	3082.02	3146.79	3212.20	3278.25	3344.98	3412.35	3480.45	33
34	2955.35	3018.93	3083.10	3147.88	3213.30	3279.36	3346.10	3413.48	3481.60	34
35	2956.40	3020.00	3084.18	3148.97	3214.40	3280.47	3347.22	3414.61	3482.74	35
36	2957.46	3021.06	3085.25	3150.05	3215.50	3281.58	3348.34	3315.75	3483.88	36
37	2958.51	3022.13	3086.33	3151.14	3216.60	3282.69	3349.46	3416.88	3485.03	37
38	2959.57	3023.20	3087.41	3152.23	3217.70	3283.80	3350.58	3418.01	3486.17	38
39	2960.63	3024.26	3088.48	3153.31	3218.80	3284.91	3351.69	3419.14	3487.32	39
40	2961.68	3025.33	3089.56	3154.40	3219.89	3286.02	3352.81	3420.28	3488.46	40
41	2962.74	3026.39	3090.64	3155.49	3220.99	3287.13	3353.93	3421.41	3489.60	41
42	2963.80	3027.46	3091.71	3156.57	3222.09	3288.24	3355.05	3422.54	3490.75	42
43	2964.85	3028.52	3092.79	3157.66	3223.19	3289.35	3356.17	3423.68	3491.89	43
44	2965.91	3029.59	3093.87	3158.75	3224.29	3290.46	3357.29	3424.81	3493.04	44
45	2966.96	3030.66	3094.95	3159.84	3225.38	3291.57	3358.41	3425.94	3494.18	45
46	2968.02	3031.72	3096.02	3160.92	3226.48	3292.68	3359.53	3427.07	3495.32	46
47	2969.08	3032.79	3097.10	3162.01	3227.58	3293.78	3360.65	3428.21	3496.47	47
48	2970.13	3033.85	3098.18	3163.10	3228.68	3294.89	3361.77	3429.34	3497.61	48
49	2971.19	3034.92	3099.25	3164.18	3229.78	3296.00	3362.89	3430.47	3498.77	49
50	2972.25	3035.98	3100.33	3165.27	3230.88	3297.11	3364.01	3431.60	3499.90	50
51	2973.30	3037.05	3101.41	3166.36	3231.97	3298.22	3365.13	3432.74	3501.04	51
52	2974.36	3038.11	3102.48	3167.44	3233.07	3299.33	3366.25	3433.87	3502.19	52
53	2975.41	3039.18	3103.56	3168.53	3234.17	3300.44	3367.37	3435.00	3503.33	53
54	2976.47	3040.25	3104.64	3169.62	3235.27	3301.55	3368.48	3436.13	3504.48	54
55	2977.53	3041.31	3105.72	3170.71	3236.37	3302.66	3369.60	3437.27	3505.62	55
56	2978.58	3042.38	3106.79	3171.79	3237.47	3303.77	3370.72	3438.40	3506.76	56
57	2979.64	3043.44	3107.87	3172.88	3238.56	3304.88	3371.84	3439.53	3507.91	57
58	2980.70	3044.51	3108.95	3173.97	3239.66	3305.99	3372.96	3440.67	3509.05	58
59	2981.75	3045.57	3110.02	3175.05	3240.76	3307.10	3374.08	3441.80	3510.20	59

RAILROAD CURVE TABLES.

′	63°	64°	65°	66°	67°	68°	69°	70°	71°	′
0	3511.34	3580.45	3650.41	3721.06	3792.57	3864.88	3938.11	4012.15	4087.15	0
1	3512.49	3581.61	3651.59	3722.25	3793.77	3866.10	3939.34	4013.40	4088.41	1
2	3513.64	3582.78	3652.76	3723.44	3794.97	3867.31	3940.57	4014.64	4089.67	2
3	3514.78	3583.94	3653.94	3724.62	3796.17	3868.53	3941.80	4015.89	4090.93	3
4	3515.93	3585.10	3655.11	3725.81	3797.38	3869.75	3943.03	4017.14	4092.19	4
5	3517.08	3586.27	3656.29	3727.00	3798.58	3870.97	3944.26	4018.39	4093.45	5
6	3518.23	3587.43	3657.46	3728.19	3799.78	3872.18	3945.49	4019.63	4094.71	6
7	3519.38	3588.59	3658.64	3729.38	3800.98	3873.40	3946.72	4020.88	4095.97	7
8	3520.52	3589.75	3659.81	3730.56	3802.18	3874.62	3947.95	4022.13	4097.24	8
9	3521.67	3590.92	3660.99	3731.75	3803.38	3875.83	3949.18	4023.37	4098.50	9
10	3522.82	3592.08	3662.16	3732.94	3804.58	3877.05	3950.41	4024.62	4099.76	10
11	3523.97	3593.24	3663.33	3734.13	3805.78	3878.27	3951.64	4025.87	4101.02	11
12	3525.12	3594.41	3664.51	3735.32	3806.99	3879.48	3952.87	4027.11	4102.28	12
13	3526.26	3595.57	3665.68	3736.50	3808.19	3880.70	3954.10	4028.36	4103.54	13
14	3527.41	3596.73	3666.86	3737.69	3809.39	3881.92	3955.33	4029.61	4104.80	14
15	3528.56	3597.90	3668.03	3738.88	3810.59	3883.14	3956.56	4030.86	4106.06	15
16	3529.71	3599.06	3669.21	3740.07	3811.79	3884.35	3957.79	4032.10	4107.32	16
17	3530.86	3600.22	3670.38	3741.26	3812.99	3885.57	3959.02	4033.35	4108.58	17
18	3532.00	3601.38	3671.56	3742.44	3814.19	3886.79	3960.25	4034.60	4109.84	18
19	3533.15	3602.55	3672.73	3743.63	3815.39	3888.00	3961.48	4035.84	4111.10	19
20	3534.30	3603.71	3673.90	3744.82	3816.60	3889.21	3962.71	4037.09	4112.36	20
21	3535.45	3604.87	3675.08	3746.01	3817.80	3890.43	3963.94	4038.34	4113.62	21
22	3536.60	3606.04	3676.25	3747.20	3819.00	3891.64	3965.17	4039.58	4114.89	22
23	3537.74	3607.20	3677.43	3748.38	3820.20	3892.86	3966.40	4040.83	4116.15	23
24	3538.89	3608.36	3678.60	3749.57	3821.40	3894.08	3967.63	4042.08	4117.41	24
25	3540.04	3609.53	3679.78	3750.76	3822.60	3895.29	3968.86	4043.33	4118.67	25
26	3541.19	3610.69	3680.95	3751.95	3823.80	3896.51	3970.09	4044.57	4119.93	26
27	3542.34	3611.85	3682.13	3753.14	3825.01	3897.73	3971.32	4045.82	4121.19	27
28	3543.48	3613.01	3683.30	3754.32	3826.21	3898.95	3972.55	4047.07	4122.45	28
29	3544.63	3614.18	3684.48	3755.51	3827.41	3900.16	3973.78	4048.31	4123.71	29
30	3545.78	3615.34	3685.65	3756.70	3828.61	3901.38	3975.01	4049.56	4124.97	30
31	3546.94	3616.51	3686.83	3757.90	3829.82	3902.60	3976.25	4050.81	4126.24	31
32	3548.09	3617.68	3688.01	3759.09	3831.03	3903.83	3977.49	4052.07	4127.51	32
33	3549.25	3618.85	3689.19	3760.29	3832.24	3905.05	3978.72	4053.32	4128.78	33
34	3550.40	3620.02	3690.37	3761.48	3833.45	3906.28	3979.96	4054.57	4130.05	34
35	3551.56	3621.19	3691.55	3762.68	3834.66	3907.50	3981.20	4055.83	4131.32	35
36	3552.72	3622.35	3692.73	3763.87	3835.86	3908.73	3982.44	4057.08	4132.59	36
37	3553.87	3623.52	3693.91	3765.07	3837.07	3909.95	3983.68	4058.33	4133.86	37
38	3555.03	3624.69	3695.09	3766.27	3838.28	3911.17	3984.91	4059.58	4135.13	38
39	3556.18	3625.86	3696.27	3767.46	3839.49	3912.40	3986.15	4060.84	4136.40	39
40	3557.34	3627.03	3697.45	3768.66	3840.70	3913.62	3987.39	4062.09	4137.67	40
41	3558.49	3628.20	3698.63	3769.85	3841.91	3914.85	3988.63	4063.34	4138.94	41
42	3559.65	3629.37	3699.81	3771.05	3843.12	3916.07	3989.87	4064.60	4140.21	42
43	3560.80	3630.54	3700.99	3772.24	3844.33	3917.30	3991.10	4065.85	4141.48	43
44	3561.96	3631.71	3702.17	3773.44	3845.54	3918.52	3992.34	4067.10	4142.75	44
45	3563.12	3632.88	3703.35	3774.64	3846.75	3919.74	3993.58	4068.36	4144.02	45
46	3564.27	3634.04	3704.53	3775.83	3847.95	3920.97	3994.82	4069.61	4145.29	46
47	3565.43	3635.21	3705.72	3777.03	3849.16	3922.19	3996.06	4070.86	4146.56	47
48	3566.58	3636.38	3706.90	3778.22	3850.37	3923.42	3997.29	4072.11	4147.83	48
49	3567.74	3637.55	3708.08	3779.42	3851.58	3924.64	3998.52	4073.37	4149.10	49
50	3568.89	3638.72	3709.26	3780.61	3852.79	3925.87	3999.77	4074.62	4150.37	50
51	3570.05	3639.89	3710.44	3781.81	3854.00	3927.09	4001.01	4075.87	4151.64	51
52	3571.21	3641.06	3711.62	3783.01	3855.21	3928.31	4002.25	4077.13	4152.91	52
53	3572.36	3642.23	3712.80	3784.20	3856.42	3929.54	4003.48	4078.38	4154.18	53
54	3573.52	3643.40	3713.98	3785.40	3857.63	3930.76	4004.72	4079.63	4155.45	54
55	3574.67	3644.57	3715.16	3786.59	3858.84	3931.99	4005.96	4080.89	4156.72	55
56	3575.83	3645.73	3716.34	3787.79	3860.04	3933.21	4007.20	4082.14	4157.99	56
57	3576.99	3646.90	3717.52	3788.98	3861.25	3934.44	4008.44	4083.39	4159.26	57
58	3578.14	3648.07	3718.70	3790.18	3862.46	3935.66	4009.67	4084.64	4160.53	58
59	3579.30	3649.24	3719.88	3791.38	3863.67	3936.88	4010.91	4085.90	4161.80	59

RAILROAD CURVE TABLES.

′	72°	73°	74°	75°	76°	77°	78°	79°	80°	′
0	4163.07	4239.97	4317.84	4396.74	4476.73	4557.81	4640.04	4723.41	4808.04	0
1	4164.35	4241.26	4319.15	4398.07	4478.08	4559.18	4641.43	4724.82	4809.47	1
2	4165.63	4242.56	4320.46	4399.40	4479.42	4560.54	4642.81	4726.22	4810.89	2
3	4166.90	4243.85	4321.77	4400.73	4480.77	4561.91	4644.20	4727.63	4812.32	3
4	4168.18	4245.14	4323.08	4402.06	4482.12	4563.27	4645.58	4729.03	4813.74	4
5	4169.46	4246.44	4324.39	4403.39	4483.46	4564.64	4646.97	4730.44	4815.17	5
6	4170.74	4247.73	4325.70	4404.71	4484.81	4566.01	4648.35	4731.85	4816.59	6
7	4172.02	4249.02	4327.01	4406.04	4486.16	4567.37	4649.74	4733.25	4818.02	7
8	4173.29	4250.31	4328.32	4407.37	4487.51	4568.74	4651.12	4734.66	4819.44	8
9	4174.57	4251.61	4329.63	4408.70	4488.85	4570.10	4652.50	4736.06	4820.87	9
10	4175.85	4252.90	4330.94	4410.03	4490.20	4571.47	4653.89	4737.47	4822.29	10
11	4177.13	4254.19	4332.25	4411.36	4491.55	4572.83	4655.27	4738.87	4823.72	11
12	4178.41	4255.49	4333.56	4412.69	4492.89	4574.20	4656.66	4740.28	4825.14	12
13	4179.68	4256.78	4334.87	4414.02	4494.24	4575.56	4658.04	4741.68	4826.57	13
14	4180.96	4258.07	4336.18	4415.35	4495.59	4576.93	4659.43	4743.09	4827.99	14
15	4182.24	4259.36	4337.49	4416.68	4496.93	4578.30	4660.81	4744.50	4829.42	15
16	4183.52	4260.66	4338.80	4418.01	4498.28	4579.66	4662.20	4745.90	4830.84	16
17	4184.80	4261.95	4340.11	4419.34	4499.63	4581.03	4663.58	4747.31	4832.27	17
18	4186.07	4263.24	4341.42	4420.67	4500.98	4582.39	4664.97	4748.71	4833.69	18
19	4187.35	4264.54	4342.73	4422.00	4502.32	4583.76	4666.35	4750.12	4835.12	19
20	4188.63	4265.83	4344.05	4423.33	4503.67	4585.12	4667.73	4751.52	4836.54	20
21	4189.91	4267.12	4345.36	4424.65	4505.01	4586.49	4669.12	4752.93	4837.97	21
22	4191.19	4268.42	4346.67	4425.98	4506.35	4587.86	4670.50	4754.34	4839.39	22
23	4192.46	4269.71	4347.98	4427.31	4507.70	4589.22	4671.89	4755.74	4840.82	23
24	4193.74	4271.00	4349.29	4428.64	4509.05	4590.59	4673.27	4757.15	4842.24	24
25	4195.02	4272.29	4350.60	4429.97	4510.39	4591.95	4674.66	4758.55	4843.67	25
26	4196.30	4273.59	4351.91	4431.30	4511.74	4593.32	4676.04	4759.96	4845.09	26
27	4197.57	4274.88	4353.22	4432.63	4513.09	4594.69	4677.43	4761.37	4846.52	27
28	4198.85	4276.17	4354.53	4433.96	4514.44	4596.05	4678.81	4762.77	4847.94	28
29	4200.13	4277.47	4355.84	4435.29	4515.78	4597.42	4680.20	4764.18	4849.37	29
30	4201.41	4278.76	4357.15	4436.62	4517.13	4598.78	4681.58	4765.58	4850.79	30
31	4202.70	4280.06	4358.47	4437.96	4518.49	4600.15	4682.97	4766.99	4852.23	31
32	4203.98	4281.36	4359.79	4439.29	4519.84	4601.53	4684.37	4768.41	4853.66	32
33	4205.27	4282.67	4361.11	4440.63	4521.20	4602.91	4685.76	4769.83	4855.10	33
34	4206.55	4283.97	4362.43	4441.97	4522.55	4604.28	4687.16	4771.24	4856.53	34
35	4207.84	4285.27	4363.75	4443.30	4523.91	4605.66	4688.55	4772.66	4857.97	35
36	4209.12	4286.58	4365.07	4444.64	4525.27	4607.03	4689.94	4774.07	4859.41	36
37	4210.41	4287.88	4366.39	4445.98	4526.62	4608.41	4691.34	4775.49	4860.84	37
38	4211.69	4289.18	4367.71	4447.32	4527.98	4609.78	4692.73	4776.90	4862.28	38
39	4212.98	4290.48	4369.03	4448.65	4529.33	4611.16	4694.13	4778.32	4863.71	39
40	4214.26	4291.79	4370.35	4449.99	4530.69	4612.53	4695.52	4779.73	4865.15	40
41	4215.55	4293.09	4371.67	4451.33	4532.05	4613.91	4696.92	4781.15	4866.59	41
42	4216.83	4294.39	4372.99	4452.66	4533.40	4615.28	4698.31	4782.56	4868.03	42
43	4218.12	4295.69	4374.31	4454.00	4534.76	4616.66	4699.70	4783.98	4869.46	43
44	4219.40	4297.00	4375.63	4455.34	4536.11	4618.03	4701.10	4785.39	4870.90	44
45	4220.69	4298.30	4376.94	4456.67	4537.47	4619.41	4702.49	4786.81	4872.33	45
46	4221.98	4299.60	4378.26	4458.01	4538.83	4620.78	4703.89	4788.22	4873.77	46
47	4223.26	4300.91	4379.58	4459.35	4540.18	4622.16	4705.28	4789.64	4875.21	47
48	4224.55	4302.21	4380.90	4460.69	4541.54	4623.53	4706.67	4791.05	4876.64	48
49	4225.83	4303.51	4382.22	4462.02	4542.89	4624.91	4708.07	4792.47	4878.08	49
50	4227.12	4304.81	4383.54	4463.36	4544.25	4626.29	4709.47	4793.89	4879.52	50
51	4228.40	4306.12	4384.86	4464.70	4545.61	4627.66	4710 86	4795.30	4880.95	51
52	4229.69	4307.42	4386.18	4466.03	4546.96	4629.04	4712.25	4796.72	4882.39	52
53	4230.97	4308.72	4387.50	4467.37	4548.32	4630.41	4713.65	4798.13	4883.83	53
54	4232.26	4310.02	4388.82	4468.71	4549.67	4631.79	4715.04	4799.55	4885.26	54
55	4233.54	4311.33	4390.14	4470.04	4551.03	4633.16	4716.44	4800.96	4886.70	55
56	4234.83	4312.63	4391.46	4471.38	4552.39	4634.54	4717.83	4802.38	4888.13	56
57	4236.11	4313.93	4392.78	4472.72	4553.74	4635.91	4719.22	4803.79	4889.57	57
58	4237.40	4315.23	4394.10	4474.06	4555.10	4637.29	4720.62	4805.21	4891.00	58
59	4238.68	4316.54	4395.42	4475.39	4556.45	4638.66	4722.01	4806.62	4892.44	59

RAILROAD CURVE TABLES.

′	81°	82°	83°	84°	85°	86°	87°	88°	89°	′
0	4893 88	4980.97	5069.44	5159.29	5250.57	5343.28	5437.54	5533.35	5630.81	0
1	4895.33	4982.44	5070.93	5160.80	5252.11	5344.84	5439.13	5534.97	5632.46	1
2	4896.77	4983 91	5072.42	5162.32	5253.65	5346.41	5440.72	5536 59	5634.10	2
3	4898.22	4985.38	5073.92	5163.83	5255.19	5347.97	5442.31	5538.20	5635.75	3
4	4899.66	4986.85	5075.41	5165.35	5256.73	5349.54	5443.90	5539.82	5637.39	4
5	4901.11	4988.32	5076.90	5166.86	5258.27	5351.10	5445.50	5541.44	5639.04	5
6	4902.56	4989.78	5078.39	5168.38	5259.81	5352.67	5447.09	5543.06	5640.69	6
7	4904.00	4991.25	5079.88	5169.89	5261.35	5354.23	5448.68	5544.68	5642.33	7
8	4905.45	4992.72	5081 38	5171.41	5262.88	5355.79	5450.27	5546.29	5643.98	8
9	4906.89	4994.19	5082.87	5172.92	5264.42	5357.36	5451.86	5547.91	5645.63	9
10	4908.34	4995.66	5084.36	5174.44	5265.96	5358.92	5453.45	5549.53	5647.27	10
11	4909.78	4997.13	5085.85	5175.95	5267.50	5360.49	5455.04	5551.14	5648.92	11
12	4911.23	4998.60	5087.34	5177.47	5269.04	5362 05	5456.63	5552.76	5650.57	12
13	4912.68	5000.07	5088.84	5178.98	5270.58	5363.62	5458.22	5554.38	5652.21	13
14	4914.12	5001.54	5090.33	5180.50	5272.12	5365.18	5459.81	5556.00	5653.86	14
15	4915.57	5003.01	5091.82	5182.01	5273.66	5366.74	5461.41	5557.62	5655.50	15
16	4917.01	5004.47	5093.31	5183.53	5275.20	5368.31	5463.00	5559.24	5657.15	16
17	4918.46	5005.94	5094.80	5185.04	5276.74	5369.87	5464.59	5560.85	5658.80	17
18	4919.91	5007.41	5096.30	5186.55	5278.28	5371.44	5466.18	5562 47	5660.44	18
19	4921.35	5008.88	5097.79	5188.07	5279.82	5373.00	5467.77	5564.09	5662.09	19
20	4922.79	5010.35	5099.28	5189.58	5281.36	5374.57	5469.36	5565.70	5663.74	20
21	4924.24	5011.82	5100.77	5191.10	5282.90	5376.13	5470.95	5567.32	5665.38	21
22	4925.69	5013.29	5102.26	5192.61	5284.44	5377.69	5472.54	5568.94	5667.03	22
23	4927.13	5014.76	5103.76	5194.13	5285.97	5379.26	5474.13	5570.56	5668.67	23
24	4928.58	5016.23	5105.25	5195.64	5287.51	5380.82	5475.72	5572.18	5670.32	24
25	4930.02	5017.69	5106.74	5197.16	5289.05	5382.39	5477.32	5573.79	5671.97	25
26	4931.47	5019.16	5108.23	5198.67	5290.59	5383.95	5478.91	5575.41	5673.61	26
27	4932.92	5020.63	5109.72	5200.19	5292.13	5385.51	5480.50	5577.03	5675.26	27
28	4934.36	5022.10	5111.22	5201.70	5293.67	5387.08	5482.09	5578.65	5676.91	28
29	4935.81	5023.57	5112.71	5203.22	5295.21	5388.64	5483.68	5580.27	5678.55	29
30	4937.25	5025.04	5114.20	5204.73	5296.75	5390.21	5485.27	5581.88	5680.20	30
31	4938.71	5026 52	5115 70	5206.26	5298.30	5391.79	5486.87	5583.51	5681.86	31
32	4940.16	5028.00	5117.21	5207.79	5299.85	5393.37	5488.48	5585.14	5683.52	32
33	4941.62	5029.48	5118.71	5209.31	5301.40	5394.94	5490.08	5586.77	5685.18	33
34	4943.08	5030.96	5120.21	5210.84	5302.95	5396.52	5491 68	5588.40	5686.84	34
35	4944 54	5032 44	5121.72	5212.37	5304.51	5398.10	5493.29	5590.04	5688.50	35
36	4945.99	5033.92	5123.22	5213.90	5306.06	5399.68	5494.89	5591.67	5690.16	36
37	4947.45	5035.40	5124.72	5215.43	5307.61	5401.25	5496.49	5593.30	5691.82	37
38	4948.91	5036.88	5126.22	5216 95	5309.16	5402.83	5498.09	5594.93	5693.48	38
39	4950.36	5038 36	5127.73	5218.48	5310.71	5404.41	5499.70	5596.56	5695.14	39
40	4951.82	5039.84	5129.23	5220.01	5312.26	5405.99	5501.30	5598.19	5696.80	40
41	4953.28	5041.32	5130.73	5221.54	5313.81	5407.56	5502.90	5599.82	5698.46	41
42	4954.74	5042.80	5132.24	5223 07	5315.36	5409.14	5504.50	5601.45	5700.12	42
43	4956.19	5044.28	5133 74	5224.59	5316.91	5410.72	5506.11	5603.08	5701.78	43
44	4957.65	5045.76	5135.24	5226.12	5318.46	5412.30	5507.71	5604.71	5703.44	44
45	4959.11	5047.24	5136.75	5227.65	5320.02	5413.88	5509.31	5606.35	5705.10	45
46	4960.57	5048.72	5138.25	5229.18	5321 57	5415.45	5510.91	5607.98	5706.76	46
47	4962.02	5050 20	5139.75	5230.71	5323.12	5417.03	5512.52	5609.61	5708.42	47
48	4963.48	5051.68	5141.25	5232.23	5324.67	5418.61	5514.12	5611.24	5710.08	48
49	4964.94	5053.16	5142.76	5233.76	5326.22	5420.19	5515.72	5612.87	5711.74	49
50	4966.40	5054.64	5144 26	5235.29	5327.77	5421.76	5517.32	5614.50	5713.40	50
51	4967.85	5056.12	5145.76	5236.82	5329 32	5423.34	5518.93	5616.13	5715.06	51
52	4979.31	5057.60	5147.27	5238.35	5330.87	5424.92	5520.53	5617.76	5716.72	52
53	4970.77	5059.08	5148.77	5239.87	5332.42	5426.50	5522.13	5619.39	5718 38	53
54	4972.22	5060.56	5150.27	5241.40	5333.97	5428.07	5523.74	5621.02	5720.04	54
55	4973.68	5062.04	5151.77	5242.93	5335.53	5429.65	5525.34	5622.66	5721.70	55
56	4975.14	5063.52	5153.28	5244.46	5337.08	5431.23	5526.94	5624.29	5723.36	56
57	4976.60	5065.00	5154.78	5245.99	5338.63	5432.81	5528.54	5625.92	5725.02	57
58	4978.05	5066.48	5156.28	5247.51	5340.18	5434 39	5530.15	5627.55	5726.68	58
59	4979.51	5067.96	5157.79	5249.04	5341.73	5435.96	5531.75	5629.18	5728.34	59

Table of Minutes with Corresponding Decimals.				Table of Seconds with Corresponding Decimals.			
M.	D.	M.	D.	S.	D.	S.	D.
′	°	′	°	″	″	″	°
1	0.0166	31	0.5167	1	0.0002778	31	0.0086111
2	0.0333	32	0.5333	2	0.0005556	32	0.0088888
3	0.0500	33	0.5500	3	0.0008333	33	9.0091666
4	0.0667	34	0.5667	4	0.0011111	34	0.0094444
5	0.0833	35	0.5833	5	0.0013888	35	0.0097222
6	0.1000	36	0.6000	6	0.0016666	36	0.0100000
7	0.1167	37	0.6167	7	0.0019444	37	0.0102777
8	0.1333	38	0.6333	8	0.0022222	38	0.0105555
9	0.1500	39	0.6500	9	0.0025000	39	0.0108333
10	0.1667	40	0.6667	10	0.0027777	40	0.0111111
11	0.1833	41	0.6833	11	0.0030555	41	0.0113888
12	0.2000	42	0.7000	12	0.0033333	42	0.0116666
13	0.2167	43	0.7167	13	0.0036111	43	0.0119444
14	0.2333	44	0.7333	14	0.0038888	44	0.0122222
15	0.2500	45	0.7500	15	0.0041666	45	0.0125000
16	0.2667	46	0.7667	16	0.0044444	46	0.0127777
17	0.2833	47	0.7833	17	0.0047722	47	0.0130555
18	0.3000	48	0.8000	18	0.0050000	48	0.0133333
19	0.3167	49	0.8167	19	0.0052777	49	0.0136111
20	0.3333	50	0.8333	20	0.0055555	50	0.0138888
21	0.3500	51	0.8500	21	0.0058333	51	0.0141666
22	0.3667	52	0.8667	22	0.0061111	52	0.0144444
23	0.3833	53	0.8833	23	0.0063888	53	0.0147222
24	0.4000	54	0.9000	24	0.0066666	54	0.0150000
25	0.4167	55	0.9167	25	0.0069444	55	0.0152777
26	0.4333	56	0.9333	26	0.0072222	56	0.0155555
27	0.4500	57	0.9500	27	0.0075000	57	0.0158333
28	0.4667	58	0.9667	28	0.0077777	58	0.0161111
29	0.4833	59	0.9833	29	0.0080555	59	0.0163888
30	0.5000	60	1.0000	30	0.0083333	60	0.0166666

RAILROAD CURVE TABLE.

The following table shows the distance from the point of intersection of the tangent lines to the beginning of one degree curves, for each 30 minutes, the angle of deflection (= angle at centre) being known.

I. = The given angle of deflection.
II. = The sought for distance.
III. = Difference for intermediate angles.

[This table is an abridgement of the preceding one, and is to be used for approximate work in running trial curves. When the curve is sharper than five degrees it will be well, in order to secure good results, to compute T by one of the formulas given on page 17. In using both tables it should be borne in mind that the 100-foot chain can alone be used, and that the degree of curve is the angle subtended at the center by a chord 100 feet long.—THE EDITOR.]

RAILROAD CURVE TABLE.

I	II	III	I	II	III	I	II	III
0° 0′	25.00	25.0	30° 30′	1562.17	26.8	60° 30′	3341.62	33.4
1	50.02	25.0	31	1589.04	26.9	61	3375.20	33.6
1 30	75.01	25.0	31 30	1616.03	27.0	61 30	3408.95	33.8
2	99.99	25.0	32	1643.08	27.0	62	3442.93	34.0
2 30	125.03	25.0	32 30	1670.12	27.0	62 30	3477.02	34.1
3	150.07	25.0	33	1697.28	27.2	63	3511.34	34.3
3 30	175.05	25.0	33 30	1724.56	27.3	63 30	3545.78	34.4
4	200.09	25.0	34	1751.83	27.3	64	3580.45	34.7
4 30	225.13	25.0	34 30	1779.22	27.4	64 30	3615.34	34.9
5	250.17	25.0	35	1806.67	27.4	65	3650.41	35.1
5 30	275.21	25.0	35 30	1834.17	27.5	65 30	3685.65	35.2
6	300.30	25.0	36	1861.79	27.6	66	3721.06	35.4
6 30	325.35	25.0	36 30	1889.47	27.7	66 30	3756.70	35 6
7	350.44	25.1	37	1917.26	27.8	67	3792.57	35.9
7 30	375.54	25.1	37 30	1945.05	27.8	67 30	3828.61	36.0
8	400.70	25.1	38	1973.01	27.9	68	3864.88	36.3
8 30	425.79	25.1	38 30	2001.03	28.0	68 30	3901.38	36.5
9	450.95	25.1	39	2029.11	28.1	69	3938.11	36.7
9 30	476.10	25.1	39 30	2057.30	28.2	69 30	3975.01	36.9
10	501.32	25.2	40	2085.55	28.3	70	4012.15	37.1
10 30	526.53	25.2	40 30	2113.91	28.4	70 30	4049.56	37.4
11	551.74	25.2	41	2142.33	28.4	71	4087.15	37.6
11 30	576.95	25.2	41 30	2170.92	28.6	71 30	4124.97	37.8
12	602.22	25.3	42	2199.52	28.6	72	4163.07	38.1
12 30	627.55	25.3	42 30	2228.28	28.8	72 30	4201.41	38.3
13	652.87	25.3	43	2257.10	28.8	73	4239.97	38.6
13 30	678.20	25.3	43 30	2286.04	28.9	73 30	4278 76	38.8
14	703.53	25.3	44	2315.09	29.0	74	4317.84	38.9
14 30	728.97	25.4	44 30	2344.20	29.1	74 30	4357.15	39 3
15	754.35	25.4	45	2373.42	29.2	75	4396.74	39.6
15 30	779.79	25.4	45 30	2402.76	29.3	75 30	4436.62	39.9
16	805.29	25.5	46	2432.21	29.4	76	4476.73	40.1
16 30	830.79	25.5	46 30	2461.78	29.6	76 30	4517.13	40.4
17	856.35	25.5	47	2491.46	29.7	77	4557.81	40.7
17 30	881.90	25.5	47 30	2521.26	29.8	77 30	4598.78	41.0
18	907.52	25.6	48	2551.11	29.8	78	4640.04	41.3
18 30	933.18	25.6	48 30	2581.13	30.0	78 30	4681.58	41 5
19	958.86	25.7	49	2611.27	30.1	79	4723.41	41.8
19 30	984.58	25.7	49 30	2641.53	30.3	79 30	4765.58	42.2
20	1010.37	25.8	50	2671.90	30.4	80	4808.04	42.5
20 30	1036.15	25.8	50 30	2702.44	30.5	80 30	4850.79	42.7
21	1062.00	25.8	51	2733.04	30.6	81	4893.88	43.1
21 30	1089.90	25.9	51 30	2763.81	30.8	81 30	4937.25	43.3
22	1113.80	25.9	52	2794.69	30.9	82	4980.97	43.7
22 30	1139.75	25.9	52 30	2825.69	31.0	82 30	5025.04	44.1
23	1165.76	26.0	53	2856.86	31.2	83	5069.44	44.4
23 30	1191.84	26.1	53 30	2888.15	31.3	83 30	5114.20	44.8
24	1217.96	26.1	54	2919.55	31.4	84	5159.29	45.1
24 30	1244.10	26.1	54 30	2951.12	31.6	84 30	5204.73	45.4
25	1270.28	26.2	55	2982.81	31.7	85	5250.57	45.8
25 30	1296 58	26.3	55 30	3014.67	31.9	85 30	5296.75	46.2
26	1322.88	26.3	56	3046.64	32.0	86	5343.28	46.5
26 30	1349.24	26.4	56 30	3078.79	32.2	86 30	5390.21	46.9
27	1375.65	26.4	57	3111.10	32.3	87	5437.54	47.3
27 30	1402.10	26.4	57 30	3143.53	32.4	87 30	5485.27	47.7
28	1428.65	26.5	58	3176.14	32.6	88	5533.35	48.1
28 30	1455.25	26.6	58 30	3208.91	32.8	88 30	5581.88	48.5
29	1481.89	26.6	59	3241.86	32.9	89	5630.81	48.9
29 30	1508.59	26.7	59 30	3274.92	33.1	89 30	5680.20	49.4
30	1535.30	26.7	60	3308.21	33.3	90	5730.00	49.8

RAILROAD CURVES.

THE FOLLOWING TABLE SHOWS THE METHOD OF

KEEPING THE FIELD NOTES

OF A SURVEY, FROM WHICH THE CENTER LINE IS LAID ON THE MAP

From station.	To station.	Length of tangents in feet.	Length of curves in feet	Angle at intersection of tangents or angle at centre.	Course of tangent, and degree and direction of curves.	Radius of curves in feet.	No. of ft. from intersection of tangents to begng. of curve.
.....	.....	.....	.....	Tangent	S 19° 21′ E		
0.	2.		200.	7° 24′	3° 42′ L	1548.65	100.14
2.	26.		2400.	24° 00′	1° 00′ R	5730.	1217.96
26.	43.556	1755.60		Tangent	S 2° 45′ E		
43.556	61.681		1812.5	36° 15′	2° 00′ R	2865.	937.82
61.681	93.650	3196 90		Tangent	S 33° 30′ W		
93.650	102.517		886.7	13° 18′	1° 30′ L	3820.	445.37
102.517	143.90	4138.30		Tangent	S 20° 12′ W		
143.90	155.766		1186.66	23° 44′	2° 00′ L	2865.	602.02
155.766	170.43	1466.40		Tangent	S 3° 32′ E		
170.43	181.296		1086.66	21° 44′	2° 00′ R	2865.	550.00
181.296	184.506	321.00		Tangent	S 18° 12′ W		
184.506	193.195		868.89	13° 02′	1° 30′ R	3820.	436.37
193.195	213.064	1986.9		Tangent	S 31° 14′ W		
213.064	220.908		784 44	11° 46′	1° 30′ L	3820.	393.61
220.908	230.546	963.8		Tangent	S 19° 28′ W		
230.546	242.496		1195 00	23° 54′	2° 00′ R	2865.	606.37
242.496	252.356	986 00		Tangent	S 43° 22′ W		
252.356	263.756		1140.00	17° 06′	1° 30′ L	3820.	574.30
263.756	266.02	226.40		Tangent	S 26° 16′ W		
266.02	268.02		200.00	3°	1° 30′ L	3820.	100.05
268.02	277.21		918.89	27° 34′	3° L	1910.	468.55
277.21	279.21		200 00	3° 00′	1° 30′ L	3820.	100.05
279.21	289.011	980.1		Tangent	S 7° 18′ E		
289.011	291.011		200.00	3° 00′	1° 30′ R	3820.	100.05
291.011	301.422		1041.10	31° 14′	3° 00′ R	1910.	53[illegible].88
301.422	303.00		157.86	2° 22′	1° 30′ R	3820.	78.90
303.00	321.00	1800.		Tangent	S 29° 18′ W		
321.00	334.00		1300.	26°	2° L	2865.	661.44
334.	338.71	471.00		Tangent	S 3° 18′ W		
338.71	347.15		814.16	16° 53′	2° 00′ R	2865.	425.19
347.15	364.00	1685.00		Tangent	S 20° 11′ W		
364.	376.633		1263.33	37° 54′	3° "	1910.	655.80
376.633	389.53	389.70		Tangent	S 58° 05′ W		
380.53	392.38		1185.	23° 42′	2° R	2865.	601.14
392.38	402.92	1054.00		Tangent	S 81° 47′ W		
402.92	404.92		200.	3° 00′	1° 30′ L	3820.	100.05
404.92	418.198		1327.77	39° 50′	3° 00′ L	1910.	632.04
418.198	420.198	200.		Tangent	S 38° 57′ W		
420.198	441.002		2080.41	83° 13′	4° L	1432.	1272.21
441.002	442.582		158.	4° 00′	2° 32′ L	2261.87	79.99
442.582	449.	641.8		Tangent	S 48° 16′ E		
		22.262.90	22.637.31				

APPLICATION OF THE PRISMOIDAL FORMULA

IN DETERMINING THE QUANTITIES OF RAILROADS AND CANAL EXCAVATIONS AND EMBANKMENTS.

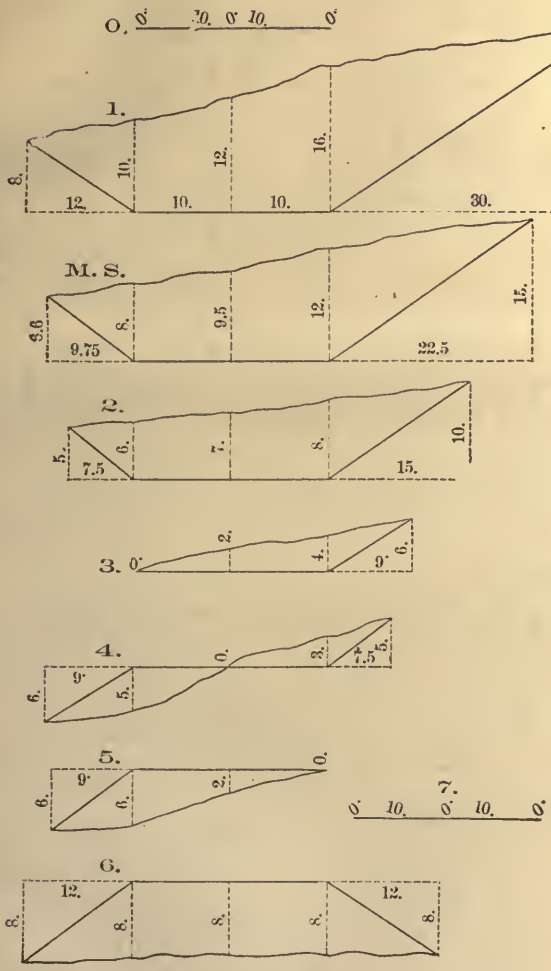
In order to obtain the mean area from transverse sections, construct from the average cuttings and average horizontal distances of the slopes of the end section, a middle section; and add to four times the area of this section the area of the end sections, and take one-sixth of the product for the mean area.

The following diagrams show most of the figures which occur in taking cross sections of railroads, and serve to illustrate the application of the formula. In practice, however, intermediate sections would be taken between station 0 and station 1, and at such other points as any sudden or material change in the surface would seem to require.

The cuttings and horizontal distances from the centre to the termination of the slopes, are set down in tabular form. The notes of the middle section may at convenience be interlined in the space between the notes of the end sections. From this form the factors for the areas are made without resorting to diagrams.—*Page* 34.

*It will be seen by inspecting the diagrams that the embankment between stations 3 and 4 assumes the shape of a pyramid, and hence one-third of the area of the embankment set opposite station 4, should be multiplied by the distance between stations 3 and 4 to obtain the quantity. Between stations 4 and 5 the excavation assumes the same form, and should also be calculated as a pyramid; or construct the middle section as before described, and calculate the distance from the centre to the point where the surface and the grade intersect; and make out the factors accordingly.

Having obtained the mean areas, proceed as hereinafter described to ascertain the cubic yards.


0.
0' 30. 0' 10. 0'
1.
8.
12.
10.
10.
12.
10.
16.
10.
30.
20.
M. S.
3.6
9.75
8.
9.5
12.
22.5
15.
2.
5.
7.5
6.
7.
8.
15.
10.
3.
0'
2.
4.
9'
6.
4.
6.
9'
5.
0.
3.
7.5
15.
5.
9'
6.
6.
2.
0.
7.
0'
10.
0'
10.
0'
6.
8.
12.
8.
8.
8.
8.
12.
8.

FIELD NOTES FOR TRANSVERSE SECTIONS.

Stations.	Distances in feet.	Left slope stake +or-	Distance from center.	Angle +or-	Center +or-	Angle +or-	Distance from center.	Right slope stake +or-	Area of Excavation.	Area of Embankment.	Mean area of Excavation.	Mean area of Embankment.	Cubic yards of Excavation.	Cubic yards of Embankment.
0	0	0	10.	0	0	0	10.	0	0					
M. S.		+4.	16.	+5.	+6.	+8.	25.	+10.	200.					
1	100	+8.	22.	+10.	+12.	+16.	40.	+20.	550.		225.		833.33	
M. S.		+6.5	19.75	+8.	+9.5	+12.	32.5	+15.	369.					
2	100	+5.	17.5	+6.	+7.	+8.	25.	+10.	222.5		374.75		1387.96	
M. S.		+2.5	13.75	+3.	+4.5	+6.	22.	+8.	131.62					
3	100	0	10.	0	+2.	+4.	19.	+6.	58.		134.5		498.14	
M. S.		—3.	14.5	—2.5	+1.	+3.5	18.25	+5.5	38.34					
4	100	—6.	19.	—5.	—0	+3.	17.5	+5.	26.25	47.5	39.60	15.83	146.66	58.62
M. S.		—6.	19.	—5.5	—1.	+1.5	13.75	+2.5		59.8				
5	100	—6.	19.	—6.	—2.	0	10.	0		77.	8.75	60.61	32.40	224.48
M. S.		—7.	20.5	—7.	—5.	—4.	16.	—4.		153.75				
6	100	—8.	22.	—8.	—8.	—8.	22.	—8.		256.		158.0		585.18
M. S.		—4.	16.	—4.	—4.	—4.	16.	—4.		104.				
7	100	0	10.	0	0	0	10.	0		0		112.0		414.81

FACTORS.

EXCAVATION.

STATION 0. AREAS.

0.——0.——0. = 000.

MIDDLE SECTION.

16. × 5. = 80.
20. × 6. =120.
25. × 8. =200.

400.÷2.=200.

STATION 1.

22. × 10. =220.
20. × 12. =240.
40. × 16. =640.

1100.÷2.=550.

MIDDLE SECTION.

19.75 × 8. =158.
9.50 × 20. =190.
32.50 × 12. =390.

738.÷2.=369.

STATION 2.

17.50 × 6. =105.
20. × 7. =140.
25. × 8. =200.

445.÷2.=222.5.

MIDDLE SECTION.

13.75 × 3. = 41.25
20. × 4.5= 90.
22. × 6. =132.

263.25.÷2.=131.62.

STATION 3.

20. × 2. = 40.
19. × 4. = 76.

116.÷2.= 58.

MIDDLE SECTION.

12.8 × 1. = 12.80
18.25 × 3.5= 63.88

76.68.÷2.= 38.34.

STATION 4.

17.5 × 3. = 52.5 ÷2.= 26.25.

STATION 5.

——————————0.

EMBANKMENT.

STATION 4. AREAS.

19. × 5. = 95.÷2.= 47.5.

MIDDLE SECTION.

19. × 5.5=104.5
15. × 1. = 15.

119.5÷2.= 59.75.

STATION 5.

19. × 6. =114.
20. × 2. = 40.

154.÷2.= 77.

MIDDLE SECTION.

20.5 × 7. =143.5
20. × 5. =100.
16. × 4. = 64.

307.5÷2.=153.75.

STATION 6.

22. × 8. =176.
20. × 8. =160.
22. × 8. =176.

512.÷2.=256.

MIDDLE SECTION.

16. × 4. = 64.
20. × 4. = 80.
16. × 4. = 64.

208.÷2=104.

STATION 7.

0.——————0.——————0.

The cubic yards between station 0 and station 1 according to the method of adding the end areas and taking one-half for the mean area - - - - = 1018.51 c. yds. } c. yds.

By 2d (or Prismoidal method)=				833.33	"	185.18
" 1st method	between	station	1 and 2 =	1430.55	"	42.59
" 2d "	"	"	1 and 2	1387.96	"	
" 1st "	"	"	2 and 3	519.44	"	21.30
" 2d "	"	"	2 and 3	498.14	"	
" 1st "	"	"	3 and 4	156.01	"	9.35
" 2d "	"	"	3 and 4	146.66	"	
" 1st "	"	"	4 and 5	48.59	"	16.19
" 2d "	"	"	4 and 5	32.40	"	

Error on 500 lineal feet of excavation - - =274.61

There are other methods which approximate nearer than the averaging method. For instance, taking $\frac{1}{2}\frac{1}{4}$ths of the difference between the end areas, (or the difference 0×0.46) and adding it to the lesser end area for the mean.

This method approximates nearer the true quantity. The principal discrepancy occurs where the embankment assumes the wedge or pryamidal form.—

By 3d	method	between station 0 and 1		937.03	cubic yards.	
" 2d	"	(or Prismoidal) 0 and 1		833.33	+	103.70
" 3d	"	between station 1 and 2		1382.03	—	5.93
" 2d	"	" "	1 and 2	1387.96		
" 3d	"	" "	2 and 3	495.08	—	3.06
" 2d	"	" "	2 and 3	498.14		
" 3d	"	" "	3 and 4	151.31	+	4.65
" 2d	"	" "	3 and 4	146.66		
" 3d	"	" "	4 and 5	44.72	+	12.32
" 2d	"	" "	4 and 5	32.40		

Error on 500 lineal feet of excavation - 111.68

Another method is to multiply $\frac{1}{6}$ of the distance between transverse sections, by the sum of the end areas, added to four times half their sum; and dividing by 27 for the cubic yards.

The results are the same as by the first method except between stations 0 and 1.

EXPLANATION OF THE FOLLOWING TABLES.

The tables are calculated for a distance of 100 feet between transverse sections.

In the left hand column are given the areas in feet. To obtain the cubic yards for areas, without decimals, look in the second column under the head of 0, and opposite the given area, find the cubic yards.

EXAMPLE.—Required the number of cubic yards for an area of 190 feet. In the second column, under the head of 0, and opposite 190 in the first column, find 703.70 cubic yards.

To obtain the cubic yards for a less distance than 100 feet, multiply the cubic yards found in the tables by the given distance, and point off the fractional parts of 100 feet.

If the area has decimal parts, pass the eye to the right, opposite the area of the whole number, and under the head of such decimal will be found the number of yards.

EXAMPLE.—Required the cubic yards for an area of 105.4 feet. In the sixth column, under the head of 40, and opposite 105 in the first column, are given 390.37 cubic yards.

If the yards for an area greater than 359.90, and not exceeding 3599 feet, are required, the decimal point of the area given in the tables, and that of the cubic yards, being removed one figure to the right, will give the required yards. If there are decimal parts, add the cubic yards found opposite 0 in the first column, under the head of such decimal.

EXAMPLE.—Required the cubic yards for an area of 1975 feet; remove the decimal point one figure to the left, and find the yards for an area of 197.5 feet = 731.48, then remove the decimal point one figure to the right and you have 7314.8 cubic yards. If there is a decimal, add the cubic yards found for such decimal.

Or, to obtain the cubic yards for an area exceeding 3599 feet, take one half of the area, and seek the corresponding yards in tables and multiply the same by 2.

EXCAVATION AND EMBANKMENT TABLES.

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
0	0.00	0.37	0.74	1.11	1.48	1.85	2.22	2.59	2.96	3.33
1	3.70	4.07	4.45	4.81	5.19	5.56	5.93	6.30	6.67	7.04
2	7.41	7.78	8.15	8.52	8.89	9.26	9.63	10.00	10.37	10.74
3	11.11	11.48	11.85	12.22	12.59	12.96	13.33	13.70	14.07	14.44
4	14.82	15.19	15.56	15.93	16.30	16.67	17.04	17.41	17.78	18.15
5	18.52	18.89	19.26	19.63	20.00	20.37	20.74	21.11	21.48	21.85
6	22.22	22.59	22.96	23.33	23.70	24.07	24.44	24.82	25.19	25.56
7	25 93	26.30	26.67	27.04	27.41	27.78	28.15	28.52	28.89	29.26
8	29 63	30.00	30.37	30.74	31.11	31.48	31.85	32.22	32.59	32.96
9	33.33	33.70	34.07	34.44	34.82	35.19	35.56	35.93	36.30	36.67
10	37.04	37.41	37.78	38.15	38.52	38.89	39.26	39.63	40.00	40.37
11	40 74	41.11	41.48	41.85	42.22	42.59	42.96	43.33	43.70	44.07
12	44.44	44.82	45.19	45.56	45.93	46.30	46.67	47.04	47.41	47.78
13	48.15	48.52	48.89	49.26	49.63	50.00	50.37	50.74	51.11	51.48
14	51 85	52.22	52.59	52.96	53.33	53.70	54.07	54.44	54 82	55.19
15	55.56	55.93	56.30	56.67	57.04	57.41	57.78	58.15	58.52	58.89
16	59 26	59.63	60.00	60.37	60.74	61.11	61.48	61.85	62.22	62.59
17	62.96	63.33	63.70	64.07	64.44	64.82	65.19	65.56	65.93	66.30
18	66.67	67.04	67.41	67.78	68.15	68.52	68.89	69.26	69.63	70.00
19	70.37	70.74	71.11	71.48	71.85	72.22	72.59	72.96	73.33	73 70
20	74.07	74 44	74 82	75.19	75.56	75.93	76.30	76.67	77.04	77.41
21	77.78	78.15	78.52	78.89	79.26	79.63	80.00	80.37	80.74	81.11
22	81.48	81.85	82.22	82.59	82.96	83.33	83.70	84.07	84.44	84.82
23	85.19	85.56	85.93	86.30	86.67	87.04	87.41	87.78	88.15	88.52
24	88.89	89.26	89 63	90.00	90.37	90.74	91.11	91.48	91.85	92.22
25	92.59	92 96	93.33	93.70	94.07	94.44	94.82	95.19	95.56	95.93
26	96.30	96.67	97.04	97.41	97.78	98.15	98.52	98.89	99.26	99 63
27	100.00	100.37	100.74	101.11	101.48	101.85	102.22	102.59	102.96	103.33
28	103.70	104.07	104.44	104.82	105.19	105.56	105.93	106.30	106.67	107.04
29	107.41	107.78	108.15	108.52	108.89	109.26	109.63	110.00	110.37	110.74
30	111.11	111.48	111.85	112.22	112.59	112.96	113.33	113.70	114.07	114.44
31	114.81	115.18	115 56	115.92	116.29	116.67	117.03	117.40	117.77	118.15
32	118.52	118.89	119.26	119.63	120.00	120.37	120.74	121.11	121.48	121.85
33	122 22	122 59	122.96	123.33	123.70	124.07	124.44	124.81	125.18	125.55
34	125.92	126.30	126.66	127.03	127.40	127.77	128.14	128 51	128.88	129.26
35	129.63	130 00	130 37	130.74	131.11	131.48	131.85	132.22	132.59	132.96
36	133.33	133.70	134.07	134.44	134.81	135.18	135.55	135 92	136.29	136.67
37	137.04	137.41	137.78	138.15	138.52	138.89	139.26	139.63	140.00	140 37
38	140.74	141.11	141.48	141.85	142.22	142.59	142.96	143.33	143.70	144.07
39	144.44	144.81	145.18	145.55	145.92	146.29	146.66	147.03	147.40	147.78
40	148.15	148.52	148.89	149.26	149.63	150.00	150.37	150.74	151.11	151.48
41	151.85	152.22	152.59	152.96	153.33	153.70	154.07	154.44	154.81	155 18
42	155.55	155.92	156.29	156.66	157.03	157.40	157.77	158.14	158.51	158.89
43	159.26	159.63	160 00	160.37	160.74	161.11	161.48	161.85	162.22	162 59
44	162.96	163.33	163.70	164.07	164.44	164.81	165.18	165.55	165.92	166.30
45	166.67	167 04	167.41	167.78	168.15	168.52	168.89	169.26	169.63	170.00
46	170.37	170.74	171.11	171.48	171.85	172.22	172.59	172.96	173.33	173.70
47	174.07	174.44	174.81	175.18	175.55	175.92	176.29	176.66	177.03	177.41
48	177.78	178.15	178.52	178.89	179.26	179.63	180.00	180.37	180.74	181.11
49	181.48	181.85	182.22	182.59	182.96	183.33	183.70	184.07	184.44	184.81
50	185.18	185.55	185 92	186.29	186.66	187.03	187.40	187.77	188.14	188 52
51	188.89	189.26	189.63	190.00	190.37	190.74	191.11	191.48	191.85	192.22
52	192 59	192.96	193.33	193.70	194.07	194.44	194.81	195.18	195.55	195.93
53	196.30	196.67	197.04	197.41	197.78	198.15	198.52	198 89	199.26	199 63
54	200.00	200.37	200.74	201.11	201.48	201.85	202.22	202.59	202.96	203.33
55	203.70	204.07	204.44	204.81	205.18	205.55	205.92	206 29	206.66	207.03
56	207.41	207.78	208.15	208.52	208.89	209.26	209.63	210 00	210.37	210.74
57	211.11	211.48	211.85	212.22	212.59	212.96	213.33	213.70	214.07	214.44
58	214.81	215.18	215.55	215.92	216.29	216.66	217.03	217.40	217.77	218.15
59	218.52	218.89	219.26	219.63	220.00	220.37	220.74	221.11	221.48	221.85

EXCAVATION AND EMBANKMENT TABLES.

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
60	222.22	222.59	222.96	223.33	223.70	224.07	224.44	224.81	225.18	225.55
61	225.92	226.29	226.66	227.03	227.40	227.77	228.14	228.51	228.88	229.26
62	229.63	230.00	230.37	230.74	231.11	231.48	231.85	232.22	232.59	232.96
63	233.33	233.70	234.07	234.44	234.81	235.18	235.55	235.92	236.29	236.67
64	237.04	237.41	237.78	238.15	238.52	238.89	239.26	239.63	240.00	240.37
65	240.74	241.11	241.48	241.85	242.22	242.59	242.96	243.33	243.70	244.07
66	244.44	244.81	245.18	245.55	245.92	246.30	246.67	247.04	247.41	247.78
67	248.15	248.52	248.89	249.26	249.63	250.00	250.37	250.74	251.11	251.48
68	251.85	252.22	252.59	252.96	253.33	253.70	254.07	254.44	254.81	255.18
69	255.56	255.93	256.30	256.67	257.04	257.41	257.78	258.15	258.52	258.89
70	259.26	259.63	260.00	260.37	260.74	261.11	261.48	261.85	262.22	262.59
71	262.96	263.33	263.70	264.07	264.44	264.81	265.18	265.55	265.92	266.30
72	266.67	267.04	267.41	267.78	268.15	268.52	268.89	269.26	269.63	270.00
73	270.37	270.74	271.11	271.48	271.85	272.22	272.59	272.96	273.33	273.70
74	274.07	274.44	274.81	275.18	275.55	275.92	276.29	276.66	277.04	277.41
75	277.78	278.15	278.52	278.89	279.26	279.63	280.00	280.37	280.74	281.11
76	281.48	281.85	282.22	282.59	282.96	283.33	283.70	284.07	284.44	284.81
77	285.18	285.56	285.93	286.30	286.67	287.04	287.41	287.78	288.15	288.52
78	288.89	289.26	289.63	290.00	290.37	290.74	291.11	291.48	291.85	292.22
79	292.59	292.96	293.33	293.70	294.07	294.44	294.81	295.18	295.55	295.93
80	296.30	296.67	297.04	297.41	297.78	298.15	298.52	298.89	299.26	299.63
81	300.00	300.37	300.74	301.11	301.48	301.85	302.22	302.59	302.96	303.33
82	303.70	304.07	304.44	304.81	305.18	305.55	305.92	306.29	306.66	307.03
83	307.41	307.78	308.15	308.52	308.89	309.26	309.63	310.00	310.37	310.74
84	311.11	311.48	311.85	312.22	312.59	312.96	313.33	313.70	314.07	314.44
85	314.81	315.19	315.56	315.93	316.30	316.67	317.04	317.41	317.78	318.15
86	318.52	318.89	319.26	319.63	320.00	320.37	320.74	321.11	321.48	321.85
87	322.22	322.59	322.96	323.33	323.70	324.07	324.44	324.81	325.18	325.55
88	325.92	326.30	326.67	327.04	327.41	327.78	328.15	328.52	328.89	329.26
89	329.63	330.00	330.37	330.74	331.11	331.48	331.85	332.22	332.59	332.96
90	333.33	333.70	334.07	334.44	334.81	335.18	335.55	335.92	336.29	336.67
91	337.04	337.41	337.78	338.15	338.52	338.89	339.25	339.62	339.99	340.37
92	340.74	341.11	341.48	341.85	342.22	342.59	342.96	343.33	343.70	344.07
93	344.44	344.81	345.18	345.56	345.93	346.30	346.67	347.03	347.40	347.78
94	348.15	348.52	348.89	349.26	349.63	350.00	350.37	350.74	351.11	351.48
95	351.85	352.22	352.59	352.96	353.33	353.70	354.07	354.44	354.81	355.18
96	355.55	355.93	356.30	356.67	357.04	357.41	357.78	358.15	358.52	358.89
97	359.26	359.63	360.00	360.37	360.74	361.11	361.48	361.85	362.22	362.59
98	362.96	363.33	363.70	364.07	364.44	364.81	365.18	365.55	365.93	366.30
99	366.67	367.04	367.41	367.78	368.15	368.52	368.89	369.26	369.63	370.00
100	370.37	370.74	371.11	371.48	371.85	372.22	372.59	372.96	373.33	373.70
101	374.07	374.44	374.81	375.18	375.55	375.92	376.29	376.67	377.04	377.41
102	377.78	378.15	378.52	378.89	379.26	379.63	380.00	380.37	380.74	381.11
103	381.48	381.85	382.22	382.59	382.96	383.33	383.70	384.07	384.44	384.81
104	385.18	385.55	385.92	386.29	386.67	387.04	387.41	387.78	388.15	388.52
105	388.89	389.26	389.63	390.00	390.37	390.74	391.11	391.48	391.85	392.22
106	392.59	392.96	393.33	393.70	394.07	394.44	394.81	395.18	395.55	395.92
107	396.30	396.67	397.04	397.41	397.78	398.15	398.52	398.89	399.26	399.63
108	400.00	400.37	400.74	401.11	401.48	401.85	402.22	402.59	402.96	403.33
109	403.70	404.07	404.44	404.81	405.18	405.55	405.92	406.29	406.67	407.04
110	407.41	407.78	408.15	408.52	408.89	409.26	409.63	410.00	410.37	410.74
111	411.11	411.48	411.85	412.22	412.59	412.96	413.33	413.70	414.07	414.44
112	414.81	415.18	415.55	415.92	416.29	416.67	417.04	417.41	417.78	418.15
113	418.52	418.89	419.26	419.63	420.00	420.37	420.74	421.11	421.48	421.85
114	422.22	422.59	422.96	423.33	423.70	424.07	424.44	424.81	425.18	425.56
115	425.93	426.30	426.67	427.04	427.41	427.78	428.15	428.52	428.89	429.26
116	429.63	430.00	430.37	430.74	431.11	431.48	431.85	432.22	432.59	432.96
117	433.33	433.70	434.07	434.44	434.81	435.18	435.55	435.92	436.29	436.67
118	437.04	437.41	437.78	438.15	438.52	438.89	439.26	439.63	440.00	440.37
119	440.74	441.11	441.48	441.85	442.22	442.59	442.96	443.33	443.70	444.07

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
120	444.44	444.81	445.18	445.55	445.92	446.29	446.67	447 04	447.41	447.78
121	448.15	448.52	448.89	449.26	449.63	450.00	450.37	450.74	451.11	451.48
122	451.85	452.22	452.59	452.96	453.33	453.70	454.07	454.44	454.81	455.18
123	455.55	455.92	456.29	456.67	457.04	457.41	457.78	458.15	458.52	458.89
124	459.26	459.63	460.00	460.37	460.74	461.11	461.48	461.85	462.22	462.59
125	462.96	463.33	463.70	464.07	464.44	464.81	465.18	465.55	465.93	466.30
126	466.67	467.04	467.41	467.78	468.15	468.52	468.89	469.26	469.63	470.00
127	470.37	470.74	471.11	471.48	471.85	472.22	472.59	472.96	473.33	473.70
128	474.07	474.44	474.81	475.18	475.56	475.93	476.30	476.67	477.04	477.41
129	477.78	478.15	478.52	478.89	479.26	479.63	480.00	480.37	480.74	481.11
130	481.48	481.85	482.22	482.59	482.96	483.33	483.70	484.07	484.44	484.81
131	485.18	485.55	485.92	486.29	486.67	487.04	487.41	487.78	488.15	488.52
132	488.89	489.26	489.63	490.00	490.37	490.74	491.11	491.48	491.85	492.22
133	492.59	492.96	493.33	493.70	494.07	494.44	494.81	495.19	495.56	495.93
134	496.30	496.67	497.04	497.41	497.78	498.15	498.52	498.89	499.26	499.63
135	500.00	500.37	500.74	501.11	501.48	501.85	502.22	502.59	502.96	503.33
136	503.70	504.07	504.44	504.81	505.18	505.56	505.93	506.30	506.67	507.04
137	507.41	507.78	508.15	508.52	508.89	509.26	509.63	510.00	510.37	510.74
138	511.11	511.48	511.85	512.22	512.59	512.96	513.33	513.70	514.07	514.44
139	514.81	515.18	515.55	515.92	516.29	516.67	517.04	517.41	517.78	518.15
140	518.52	518.89	519.26	519.63	520.00	520.37	520.74	521.11	521.48	521.85
141	522.22	522.59	522.96	523.33	523.70	524.07	524.44	524.81	525.19	525.56
142	525.93	526.30	526.67	527.04	527.41	527.78	528.15	528.52	528.89	529.26
143	529.63	530.00	530.37	530.74	531.11	531.48	531.85	532.22	532.59	532.94
144	533.33	533.70	534.07	534.44	534.81	535.18	535.56	535.93	536.30	536.67
145	537.04	537.41	537.78	538.15	538.52	538.89	539.26	539.63	540.00	540.37
146	540.74	541.11	541.48	541.85	542.22	542.59	542.96	543.33	543.70	544.07
147	544.44	544.81	545.18	545.56	545.93	546.30	546.67	547.04	547.41	547.78
148	548.15	548.52	548.89	549.26	549.63	550.00	550.37	550.74	551.11	551.48
149	551.85	552.22	552.59	552.96	553.33	553.70	554.07	554.44	554.81	555.18
150	555.55	555.93	556.30	556.67	557.04	557.41	557.78	558.15	558.52	558.89
151	559.26	559.63	560.00	560.37	560.74	561.11	561.48	561.85	562.22	562.59
152	562.96	563.33	563.70	564.07	564.44	564.81	565.18	565.56	565.93	566.30
153	566.67	567.04	567.41	567.78	568.15	568.52	568.89	569.26	569.63	570.00
154	570.37	570.74	571.11	571.48	571.85	572.22	572.59	572.96	573.33	573.70
155	574.07	574.44	574.81	575.18	575.56	575.93	576.30	576.67	577.04	577.41
156	577.78	578.15	578.52	578.89	579.26	579.63	580.00	580.37	580.74	581.11
157	581.48	581.85	582.22	582.59	582.96	583.33	583.70	584.07	584.44	584.81
158	585.18	585.55	585.92	586.29	586.66	587.04	587.41	587.78	588.15	588.52
159	588.89	589.26	589.63	590.00	590.37	590.74	591.11	591.48	591.85	592 22
160	592.59	592.96	593.33	593.70	594.07	594.44	594.81	595.18	595.55	595.92
161	596.29	596.67	597.04	597.41	597.78	598.15	598.52	598.89	599.26	599.63
162	600.00	600.37	600.74	601.11	601.48	601.85	602.22	602.59	602.96	603.33
163	603.70	604.07	604.44	604.81	605.18	605.55	605.92	606.30	606.67	607.04
164	607.41	607.78	608.15	608.52	608.89	609.26	609.63	610.00	610.37	610.74
165	611.11	611.48	611.85	612.22	612.59	612.96	613.33	613.70	614.07	614.44
166	614.81	615.18	615.55	615.92	616.29	616.67	617.04	617.41	617.78	618.15
167	618.52	618.89	619.26	619.63	620.00	620.37	620.74	621.11	621.48	621.85
168	622.22	622.59	622.96	623.33	623.70	624.07	624.44	624.81	625.18	625.56
169	625.93	626.30	626.67	627.04	627.41	627.78	628.15	628.52	628.89	629.26
170	629.63	630.00	630.37	630.74	631.11	631.48	631.85	632.22	632.59	632.96
171	633.33	633.70	634.07	634.44	634.81	635.18	635.55	635.92	636.29	636.66
172	637.04	637.40	637.77	638.14	638.51	638.88	639.25	639.62	639.99	640.37
173	640.74	641.11	641.48	641.85	642.22	642.59	642.96	643.33	643.70	644.07
174	644.44	644.81	645.18	645.55	645.92	646.29	646.66	647.03	647.41	647.78
175	648.15	648.52	648.89	649 26	649.63	650.00	650.37	650.74	651.11	651.48
176	651.85	652.22	652.59	652.96	653.33	653.70	654.07	654.44	654.81	655.18
177	655.56	655.93	656.30	656.67	657.04	657.41	657.78	658.15	658.52	658.89
178	659.26	659.63	660.00	660.37	660.74	661.11	661.48	661.85	662.22	662.59
179	662.96	663.33	663.70	664.07	664.44	664.81	665.18	665.55	665.92	666.29

EXCAVATION AND EMBANKMENT TABLES.

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
180	666.67	667.04	667.41	667.78	668.15	668.52	668.89	669.26	669.63	670.00
181	670.37	670.74	671.11	671.48	671.85	672.22	672.59	672.96	673.33	673.70
182	674.07	674.44	674.81	675.18	675.55	675.93	676 30	676.67	677.04	677.41
183	677.78	678.15	678.52	678.89	679.26	679.63	680.00	680.37	680.74	681.11
184	681.48	681.85	682.22	682.59	682.96	683.33	684.70	684.07	684.44	684.81
185	685.18	685.56	685.93	686 30	686.67	687.04	687.41	687.78	688.15	688.52
186	688.89	689.26	689.63	690.00	690.37	690.74	691.11	691.48	691.85	692.22
187	692.59	692.96	693.33	693 70	694.07	694.44	694.81	695.18	695.55	695.92
188	696.30	696.67	697.04	697.41	697.78	698.15	698.52	698.89	699.26	699.63
189	700.00	700.37	700.74	701.11	701.48	701.85	702.22	702.59	702.96	703.33
190	703.70	704.07	704.44	704.81	705.18	705.55	705.92	706.29	706.66	707.03
191	707.40	707.77	708.14	708.51	708.89	709.26	709 63	710.00	710.37	710.74
192	711.11	711.48	711.85	712 22	712.59	712.96	713.33	713.70	714.07	714.44
193	714.81	715.18	715.55	715.92	716.29	716.67	717.04	717.41	717.78	718.15
194	718.52	718.89	719.26	719.63	720 00	720.37	720.74	721.11	721.48	721.85
195	722.22	722.59	722.96	723.33	723.70	724.07	724.44	724.81	725.18	725.55
196	725.92	726.29	726.66	727.03	727.40	727.77	728.14	728.51	728.88	729.25
197	729.63	730.00	730.37	730.74	731.11	731.48	731.85	732.22	732.59	732.96
198	733.33	733.70	734.07	734.44	734.81	735.18	735.55	735.93	736.30	736.67
199	737.04	737.41	737.78	738.15	738.52	738.89	739.26	739.63	740.00	740.37
200	740.74	741.11	741.48	741.85	742.22	742.59	742.96	743.33	743.70	744.07
201	744.44	744.81	745.18	745 55	745.93	746.30	746.67	747.04	747.41	747.78
202	748.15	748.52	748.89	749. 6	749.63	750.00	750.37	750.74	751.11	751.48
203	751.85	752.22	752.59	752.96	753.33	753.70	754.07	754.44	754.81	755.18
204	755.55	755.93	756.30	756.67	757.04	757.41	757.78	758.15	758.52	758.89
205	759.26	759.63	760.00	760.37	760.74	761.11	761.48	761.85	762.22	762.59
206	762.96	763.33	763.70	764.07	764.44	764.81	765.18	765.55	765.93	766.30
207	766.66	767.04	767.41	767.78	768.15	768.52	768 89	769.26	769.63	770.00
208	770.37	770.74	771.11	771.48	771.85	772.22	772.59	772.96	773.33	773.70
209	774.07	774.44	774.81	775.18	775.55	775.93	776.30	776.66	777.04	777.41
210	777.78	778.15	778.52	778.89	779.26	779.63	780.00	780.37	780.74	781.11
211	781.48	781.85	782.22	782 59	782.96	783.33	783.70	784.07	784.44	784.81
212	785.18	785.55	785.93	786 30	786.66	787.04	787.41	787.78	788.15	788.52
213	788.89	789.26	789.63	790.00	790.37	790.74	791.11	791.48	791.85	792.22
214	792.59	792.96	793.33	793.70	794.07	794.44	794.81	795.18	795.55	795.93
215	796.30	796.66	797.04	797.41	797.78	798.15	798.52	798.89	799.26	799.63
216	800.00	800.37	800.74	801.11	801.48	801.85	802.22	802.59	802.96	803.33
217	803.70	804.07	804.44	804 81	805.18	805.55	805.93	806.30	806.66	807.04
218	807.41	807.78	808.15	808.52	808.89	809.26	809 63	810.00	810.37	810.74
219	811.11	811.48	811.85	812.22	812.59	812.96	813.33	813.70	814.07	814.44
220	814.81	815.18	815.55	815.93	816.30	816.66	817.04	817.41	817.78	818.15
221	818.52	818.89	819.26	819.63	8.0.00	820.37	820.74	821.11	821.48	821.85
222	822.22	822.59	822.96	823.33	823.70	824.07	824.44	824.81	825.18	825.55
223	825.93	826.30	826.66	827.04	827.41	827.78	828.15	828.52	828.89	829.26
224	829.63	830.00	830.37	830.74	831.11	831.48	831.85	832.22	832.59	832.96
225	833.33	833.70	834.07	834.44	834.81	835.18	835 55	835.93	836.30	836.66
226	837.04	837.41	837.78	838 15	838.52	838.89	839 26	839.63	840.00	840.37
227	840.74	841.11	841.48	841.85	842.22	842.59	842.96	843.33	843.70	844.07
228	844.44	844.81	845.18	845.55	845.93	846.30	846 66	847.04	847.41	847.78
229	848.15	848.52	848.89	849.26	849.63	850.00	850.37	850.74	851.11	851.48
230	851.85	852.22	852.59	852.96	853.33	853.70	854.07	854.44	854.81	855.18
231	855.55	855.93	856.30	856.66	857 04	857.41	857.78	858.15	858.52	858.89
232	859.26	859.63	860.00	860.37	860.74	861.11	861.48	861.85	862.22	862.59
233	862.96	863.33	863.70	864 07	864.44	864.81	865.18	865.55	865.93	866.30
234	866.66	867.04	867.41	867.78	868.15	868.52	868.89	869.26	869.63	870 00
235	870.37	870.74	871.11	871.48	871.85	872.22	872.59	872.96	873.33	873.70
236	874.07	874.44	874.81	875.18	875.55	875.93	876.30	876.66	877.04	877.41
237	877.78	878.15	878.52	878.89	879.26	879.63	880.00	880.37	880 74	881.11
238	881.48	881.85	882.22	882.59	882 96	883.33	883 70	884.07	884.44	884.81
239	885.18	885.55	885.93	886.30	886.66	887.04	887.41	887.78	888.15	888.52

EXCAVATION AND EMBANKMENT TABLES.

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
240	888.88	889.26	889.63	890.00	890.37	890.74	891.11	891.48	891.85	892.22
241	892.59	892.96	893.33	893.70	894.07	894.44	894.81	895.18	895.55	895.93
242	896.30	896.66	897.04	897.41	897.78	898.15	898.52	898.88	899.26	899.63
243	900.00	900.37	900.74	901.11	901.48	901.85	902.22	902.59	902.96	903.33
244	903.70	904.07	904.44	904.81	905.18	905.55	905.93	906.30	906.66	907.04
245	907.41	907.78	908.15	908.52	908.88	909.26	909.63	910.00	910.37	910.74
246	911.11	911.48	911.85	912.22	912.59	912.96	913.33	913.70	914.07	914.44
247	914.81	915.18	915.55	915.93	916.30	916.66	917.04	917.41	917.78	918 15
248	918.52	918.88	919.26	919.63	920.00	920.37	920.74	921.11	921.48	921.85
249	922.22	922.59	922.96	923.33	923.70	924.07	924.44	924.81	925.18	925.55
250	925.92	926.30	926.66	927.04	927.41	927.78	928.15	928.52	928.88	929.26
251	929.63	930.00	930.37	930.74	931.11	931.48	931.85	932.22	932.59	932 96
252	933.33	933.70	934.07	934.44	934.81	935.18	935.55	935.92	936.30	936.66
253	937.04	937.41	937.78	938.15	938.52	938.88	939.26	939.63	940 00	940.37
254	940.74	941.11	941.48	941.85	942.22	942.59	942.96	943.33	943.70	944.07
255	944.44	944.81	945.18	945.55	945.92	946.30	946.66	947.04	947.41	947.78
256	948.15	948.52	948.88	949.26	949.63	950.00	950.37	950.74	951.11	951.48
257	951.85	952.22	952.59	952.96	953.33	953.70	954.07	954.44	954.81	955.18
258	955.55	955.92	956.30	956.66	957.04	957.41	957.78	958.15	958.52	958.88
259	959.26	959.63	960.00	960.37	960.74	961.11	961.48	961.85	962.22	962.59
260	962.96	963.33	963.70	964.07	964.44	964.81	965.18	965.55	965.92	966.30
261	966.66	967.04	967.41	967.78	968.15	968.52	968.88	969.26	969.63	970.00
262	970.37	970.74	971.11	971.48	971.85	972.22	972.59	972.96	973.33	973.70
263	974.07	974.44	974.81	975.18	975.55	975.92	976.30	976.66	977.04	977.41
264	977.78	978.15	978.52	978.88	979.26	979.63	980.00	980.37	980.74	981.11
265	981.48	981.85	982.22	982.59	982.96	983.33	983.70	984.07	984.44	984.81
266	985.18	985.55	985.92	986.30	986.66	987.04	987.41	987.78	988.15	988.52
267	988.88	989.26	989.63	990.00	990.37	990.74	991.11	991.48	991.85	992.22
268	992.59	992.96	993.33	993.70	994.07	994.44	994.81	995.18	995.55	995.92
269	996.30	996.66	997.04	997.41	997.78	998.15	998.52	998.88	999.26	999.63
270	1000.00	1000.37	1000.74	1001.11	1001.48	1001.85	1002.22	1002.59	1002.96	1003.33
271	1003.70	1004.07	1004.44	1004.81	1005.18	1005.55	1005.92	1006.30	1006.66	1007.04
272	1007.41	1007.78	1008.15	1008.52	1008.88	1009.26	1009.63	1010.00	1010.37	1010.74
273	1011.11	1011.48	1011.85	1012.22	1012.59	1012.96	1013.33	1013.70	1014.07	1014.44
274	1014.81	1015.18	1015.55	1015.92	1016.30	1016.66	1017.04	1017.41	1017.78	1018.15
275	1018.52	1018.88	1019.26	1019.63	1020.00	1020.37	1020.74	1021.11	1021.48	1021.85
276	1022.22	1022.59	1022.96	1023.33	1023.70	1024.07	1024.44	1024.81	1025.18	1025.55
277	1025.92	1026.30	1026 66	1027.04	1027.41	1027.78	1028.15	1028.52	1028.88	1029.26
278	1029.63	1030.00	1030.37	1030.74	1031.11	1031.48	1031.85	1032.22	1032 59	1032 96
279	1033.33	1033.70	1034.07	1034.44	1034.81	1035.18	1035.55	1035.92	1036 30	1036.66
280	1037.04	1037.41	1037.78	1038.15	1038.52	1038.88	1039.26	1039.63	1040.00	1040.37
281	1040.74	1041.11	1041.48	1041.85	1042.22	1042.59	10 2.96	1043.33	1043.70	1044.07
282	1044.44	1044.81	1045.18	1045.55	1045.92	1046.30	1046.66	1047.04	1047.41	1047.78
283	1048.15	1048.52	1048.88	1049.26	1049.63	1050.00	1050.37	1050.74	1051.11	1051.48
284	1051.85	1052.22	1052 59	1052.96	1053.33	1053.70	1054.07	1054.44	1054.81	1055.18
285	1055.55	1055.92	1056.30	1056.66	1057.04	1057.41	1057.78	1058.15	1058.52	1058.88
286	1059.26	1059.63	1060.00	1060.37	1060.74	1061.11	1061.48	1061.85	1062.22	1062.59
287	1062.96	1063.33	1063.70	1064.07	1064.44	1064.81	1065.18	1065.55	1065.92	1066.30
288	1066.66	1067.04	1067.41	1067.78	1068.15	1068.52	1068.88	1069.26	1069.63	1070 00
289	1070.37	1070.74	1071.11	1071.48	1071.85	1072.22	1072.59	1072.96	1073.33	1073.70
290	1074.07	1074.44	1074 81	1075.18	1075 55	1075.92	1076.30	1076.66	1077.04	1077.41
291	1077.78	1078.15	1078.52	1078.88	1079.26	1079.63	1080.00	1080.37	1080.74	1081.11
292	1081.48	1081.85	1082.22	1082.59	1082.96	1083.33	1083.70	1084.07	1084.44	1084.81
293	1085.18	1085.55	1085.92	1086.30	1086.66	1087.04	1087.41	1087.78	1088.15	1088.52
294	1088.88	1089.26	1089.63	1090.00	1090.37	10 0.74	1091.11	1091.48	1091.85	1092.22
295	1092.59	1092.96	1093.33	1093.70	1094.07	1094.44	1094.81	1095.18	1095.55	1095.92
296	1096.30	1096.66	1097.04	1097.41	1097.78	1098.15	1098.52	1098.88	1099 26	1099.63
297	1100.00	1100.37	1100.74	1101.11	1101.48	1101.85	1102.22	1102.59	1102.96	1103.33
298	1103.70	1104.07	1104.44	1104.81	1105.18	1105.55	1105.92	1106 30	1106 66	1107.04
299	1107.41	1107.78	1108.15	1108 52	1108.88	1109.26	1109.63	1110.00	1110.37	1110.74

EXCAVATION AND EMBANKMENT TABLES.

	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
300	1111.11	1111.48	1111.85	1112.22	1112.59	1112.96	1113.33	1113.70	1114.07	1114.44
301	1114.82	1115.19	1115.56	1115.93	1116.30	1116.67	1117.04	1117.41	1117.78	1118.15
302	1118.52	1118.89	1119.26	1119.63	1120.00	1120.37	1120.74	1121.11	1121.48	1121.85
303	1122.22	1122.59	1122.96	1123.33	1123.70	1124.07	1124.44	1124.82	1125.19	1125.56
304	1125.93	1126.30	1126.67	1127.04	1127.41	1127.78	1128.15	1128.52	1128 89	1129.26
305	1129.63	1130.00	1130.37	1130.74	1131.11	1131.48	1131.85	1132.22	1132.59	1132.96
306	113[illegible].33	1133.70	1134.07	1134.44	1134.82	1135 19	1135.56	1135.93	1136 30	1137.67
307	1137.04	1137.41	1137.78	1138.15	1138.52	1138.89	1139.26	1139.63	1140.00	1140.37
308	1140.74	1141.11	1141.48	1141.85	1142.22	1142.59	1142.96	1143.33	1143.70	1144.07
309	1144.44	1144.82	1145.19	1145.56	1145.93	1146 30	1146.67	1147.04	1147.41	1147.78
310	1148.15	1148.52	1148.89	1149.[illegible]6	1149.63	1150 00	1150.37	1150.74	1151.11	1151.48
311	1151.85	1152.22	1152.59	1152.96	1153.33	1153.70	1154.07	1154.44	1154.82	1155.19
312	1155.56	1155 93	1156.30	1156.67	1157.04	1157.41	1157.78	1158.15	1158 52	1158.89
313	1159.26	1159.63	1160.00	1160.37	1160 74	1161.11	1161.48	1161.85	1162.22	1162.59
314	1162.96	1163.33	1163.70	1164.07	1164.44	1164.82	1165.19	1165.56	1165.93	1166.30
315	1166.67	1167.04	1167.41	1167.78	1168.15	1168.52	1168.89	1169.26	1169.63	1170.00
316	1170.37	1170.74	1171.11	1171.48	1171.85	1172.22	1172.59	1172.96	1173.33	1173 70
317	1174.07	1174.44	1174.82	1175.19	1175.56	1175.93	1176.30	1176.67	1177.04	1177.41
318	1177.78	1178.15	1178.52	1178.89	1179.26	1179.63	1180.00	1180.37	1180.74	1181 11
319	1181.48	1181.85	1182.22	1182.59	1182.96	1183.33	1183.70	1184.07	1184.44	1184.82
320	1185.19	1185.56	1185.93	1186.30	1186.67	1187.04	1187.41	1187.78	1188.15	1188.52
321	1188.89	1189.26	1189.63	1190.00	1190.37	1190.74	1191.11	1191.48	1191.85	1192.22
322	1192.59	1192.96	1193.33	1193.70	1194.07	1194.44	1194.82	1195.19	1195.56	1195.93
323	1196.30	1196.67	1197.04	1197.41	1197.78	1198.15	1198.52	1198.89	1199.26	1199.63
324	1200.00	1200.37	1200.74	1201.11	1201.48	1201.85	1202.22	1202.59	1202.96	1203.33
325	1203.70	1204.07	1204.44	1204.82	1205.19	1205.56	1205.93	1206.30	1206.67	1207.04
326	1207.41	1207.78	1208.15	1208.52	1208.89	1209.26	1209.63	1210.00	1210.37	1210.74
327	1211.11	1211.48	1211.85	1212.22	1212.59	1212.96	1213.33	1213.70	1214.07	1214.44
328	1214.82	1215.19	1215.56	1215.93	1216.30	1216 67	1217.04	1217.41	1217.78	1218.15
329	1218.52	1218.89	1219.26	1219.63	1220.00	1220.37	1220.74	1221.11	1221.48	1221.86
330	1222.22	1222.59	1222.96	1223.33	1223.70	1224.07	1224.44	1224.81	1225.18	1225.55
331	1225.93	1226.30	1226.67	1227.04	1227.41	1227.78	1228.15	1228.52	1228.89	1229.26
332	1229.63	1230.00	1230.37	1230.74	1231.11	1231.48	1231.85	1232.22	1232.59	1232.96
333	1233.33	1233.70	1234.07	1234.44	1234.82	1235.19	1235.56	1235.93	1236.30	1236.67
334	1237.04	1237.41	1237.78	1238.15	1238.52	1238.89	1239.26	1239.63	1240.00	1240.37
335	1240.74	1241.11	1241.48	1241.85	1242.22	1242 59	1242.96	1243 33	1243.70	1244.07
336	1244.44	1244.82	1245.19	1245.56	1245.93	1246.30	1246.67	1247.04	1247.41	1247.78
337	1248.15	1248.52	1248.89	1249.26	1249.63	1250.00	1250.37	1250.74	1251.11	1251.48
338	1251.85	1252.22	1252.59	1252.96	1253 33	1253.70	1254.07	1254.44	1254.82	1255.19
339	1255.56	1255.93	1256.30	1256.67	1257.04	1257.41	1257.73	1258.15	1258.52	1258.89
340	1259.26	1259.63	1260.00	1260.37	1260.74	1261.11	1261 48	1261.85	1262 22	1262.59
341	1262.96	1263.33	1263.70	1264.07	1264.44	1264.82	1265.19	1265.56	1265.93	1266.30
342	1266.67	1267.04	1267.41	1267.78	1268.15	1268.52	1268.89	1269.26	1269.63	1270.00
343	1270.37	1270.74	1271.11	1271.48	1271.85	1272.22	1272.59	1272.96	1273.33	1273.70
344	1274.07	1274.44	1274.82	1275.19	1275.56	1275.93	1276.30	1276.67	1277.04	1277.41
345	1277.78	1278.15	1278.52	1278.89	1279.26	1279.63	1280.00	1280.37	1280.74	1281.11
346	1281.48	1281.85	1282.22	1282.59	1282 96	1283.33	1283.70	1284.07	1284.44	1284 82
347	1285.19	1285.56	1285.93	1286.30	1286.67	1287.04	1287.41	1287.78	1288.15	1288.52
348	1288.89	1289.26	1289.63	1290.00	1290.37	1290.74	1291.11	1291.48	1291.85	1292.22
349	1292.59	1292.96	1293.33	1293.70	1294.07	1294 44	1294.82	1295.19	1295.56	1295.93
350	1296.30	1296.67	1297.04	1297.41	1297.78	1298.15	1298.52	1298 89	1299.26	1299 63
351	1300.00	1300.37	1300.74	1301.11	1301.48	1301.85	1302.22	1302.59	1302 96	1303 33
352	1303.70	1304.07	1304.44	1304.82	1305.19	1305.56	1305.93	1306.30	1306 67	1307.04
353	1307.41	1307.78	1308.15	1308.52	1308.89	1309.26	1309.63	1310.00	1310.37	1310.74
354	1311.11	1311.48	1311.85	1312.22	1312.59	1312.96	1313.33	1313.70	1314 07	1314 44
355	1314.82	1315.19	1315.56	1315.93	1316.30	1316.67	1317.04	1317.41	1317.78	1318.15
356	1318.52	1318.89	1319.26	1319.63	1320.00	1320.37	1320.74	1321.11	1321.48	1321.86
357	1322.22	1322.59	1322.96	1323.33	1323.70	1324.07	1324.44	1324.81	1325.18	1325.55
358	1325.93	1326.30	1326.67	1327.04	1327.41	1327.78	1328.15	1328.52	1328.89	1329 26
359	1329.63	1330.00	1330.37	1330.74	1331.11	1331.48	1331 85	1332.22	1332.59	1332.96

CHARLES S. CROSS, the author of the preceding pages, was graduated from the Rensselaer Polytechnic Institute in 1838. He was engaged on railroad location and construction in New York until 1852, when he went to Panama to report on the railway then there building. Returning in the same year, he was mostly employed on surveys for the location of lighthouses until 1857, when he went to Minnesota on railroad work. It was at this period that he made the computations for the tables of his pocketbook. Later he had an extensive practice in engineering field work in New York and New England, and filled many responsible positions. He was a man of great integrity of character, beloved by all who knew him. He died in Brooklyn in 1880 or 1881.—*Abstract from memoir of his life in Engineering News, May* 8, 1886.

A good engineer must be of inflexible integrity, sober, truthful, accurate, resolute, discreet, of cool and sound judgment, must have command of his temper, must have courage to resist and repel attempts at intimidation, a firmness that is proof against solicitation, flattery or improper bias of any kind, must take an interest in his work, must be energetic, quick to decide, prompt to act, must be as fair and impartial as a judge on the bench, must have experience in his work and in dealing with men, which implies some maturity of years, must have business habits and knowledge of accounts. Men who combine these qualities are not to be picked up every day. Still they can be found. But they are greatly in demand, and when found, they are worth their price; rather, they are beyond price, and their value cannot be estimated by dollars.—*Chief Engineer Starling's Report to the Miss. Levee Commissioners.*

CHAPTER II.

Engineering Field Work.*

THE SURVEYS.

The three classes of surveys, viz: Preliminary, Location, and Construction, form as good divisions as can be suggested for this subject, and we will consider them in order.

PRELIMINARY.

The object of a Preliminary survey is to ascertain whether it be feasible to build a line of railway between two points upon the surface of the earth, and this information is obtained for certain parties who wish to make money in some way or other by constructing or having such line of railroad constructed. For this purpose the parties employ a more or less competent engineer to make these surveys, giving him authority to employ one or more field parties according to the magnitude of the work, and the money they may think they can spend upon it. If only one party is employed it is sometimes under the direction of the chief engineer himself, but more commonly under an assistant employed by him.

ORGANIZATION OF FIELD PARTY.

The organization of this field party is usually, as follows:

1. The Assistant in charge of the party.
2. The Transitman, whose work is running the line and keeping all notes thereof.
3. The Leveler, whose work is taking levels, drawing the profiles and making the estimates therefrom.
4. The Level rodman, assistant to the Leveler.
5. The head chainman, who should also carry the transit rod and get therewith the lines given by the transitman.
6. The hind chainman, who should also number the stakes and keep a record of all distances measured.
7. From one to five axemen according to the amount of chopping required by the work.

---

* Written by the late CHAS. A. SMITH, C. E., Professor of Civil and Mechanical Engineering at Washington University, St. Louis, and published in ENGINEERING NEWS, Vol. III. 1876.

These may be considered about all the men needed for the professional part of the work, and if the country is inhabited will be all that will be employed; if there are only a few inhabitants a team and driver may be advantageous, but if uninhabited and it becomes necessary to take a camp outfit, at least two more men are indispensable—a teamster and a cook, the latter being a very important member of the party.

THE ENGINEER-IN-CHARGE.

The duties of the engineer-in-charge of the party are too many for enumeration here, but he has to see that the greatest amount of work possible is done for the money expended; his business is to get information for the chief engineer and to keep his party running without delay. A word of brotherly advice to him may not come amiss and is meant kindly if it is not necessary.

CARE OF MEN.

In selecting your party for a start use judgement and your knowledge of human nature; don't get two men who have a feud with each other in the same party if it can be helped. Study your men all the time and be frank and free with them; do not talk much with them in working hours, but watch all hands very closely, for the first few days especially. Remember that your men are men, and treat them well: show them that you know how the work should be done, but don't "nag" them all the time; if you have a horse, don't keep them at work till dark and then ride off and leave them to walk three or four miles to supper, but either quit work in decent season or lend your horse to some fellow who is fagged, and walk in with your men; don't hang round in the morning and let your men wait for you, but pick up an axe or rod and start first for the work; get into good training for walking, and if you start for supper last passall the men on the road; don't shirk work yourself, and don't let any body else shirk; never ask a man to do any work you would not be willing to do yourself,—we remember "stripping to the buff" and wading a stream four feet deep when the cakes of ice were coming down, because we thought the men hung back and did not want to go into the water; don't worry the transitman's wits out of his head by asking him questions; find out what he is doing and recording, but don't crowd him too hard or bluster about him; don't swear habitually before the men if you

can help it; you may want to swear at them some times, and if not used to it they will be more apt to obey; don't scold a man when you are angry yourself, if you can help it, but wait and talk to him after supper, when you have cooled down.

THE COOK.

In selecting a camp outfit be especially careful to get a good cook, and we advise a good cooking stove of cast iron with enough pipe to draw well,—we remember a sheet iron stove which had to be taken down every morning and the soot kicked out of it before a fire could be made to "draw," and we also remember the satisfaction with which the boys kicked the miserable thing to pieces after it had been "returned" at headquarters. We are more particular in this matter, not only because we like to be well fed, but because men must be well fed in order to work well—and you must remember that poor food will make bad temper and bad work, and that the interests of your employers demand that you keep your men contented with their job. So much for the *care* of the men.

ON THE LINE.

Don't let your leveler get too far behind the transit work, and see that he checks his levels and establishes benches at proper intervals. After the work is well started you will be obliged to go ahead and make yourself familiar with the features of the country and select the points where your line must be run. A preliminary line is usually run without curves, and the work of the transitman is much easier than in location surveys, and the line work is much more easily carried on than when locating; and this brings us to the work of the transitman. But before leaving this part of the subject let me remind you, that as your work progresses, you will have to come in contact with the property holders and residents of the country, and you should always bear in mind that you represent large interests and can give them by your manner a favorable or unfavorable impression as you choose.

THE TRANSITMAN.

The transitman has the hardest work of the party to perform; he has to stand with one eye at his instrument as long as the men can set stakes, and then when he is called up, the whole chain and axe force have to be idle till he arrives at the place where they are

and has set up and lined his instrument; he is supposed to direct the work in the absence of his superiors, to know the topography of the country ahead and run his line to suit the ground—to keep all the men at work and not let them loaf around—to keep all notes, and if possible sketch all the topography; to act as chie assistant in every way, to be book-keeper and cashier of the party; if in camp, to purchase supplies and see that things go right generally. The skill of the transitman in the field consists in his realization of the peculiar features of the ground and his judgment in running to them, and to his being able to work under mental pressure. The mere instrumental work in a preliminary survey is easy to do, as it consists only in running bearings, noting angles and giving the line to the men at the chain. A few words to the transitman: Carry your instrument yourself; don't let any of the men take it at night unless you are just ready to drop with fatigue. Your men may very probably offer to carry your instrument, as a common courtesy, or even to make friends with you, but don't accept such favors; among working men, from which class your chainmen and axemen will most probably come, there is but one standard of comparison, and that is strength, and although one of them may be perfectly willing to shoulder your fifteen pound transit for three or four miles, you will not gain his respect by letting him do it for you. If you have not strength, make up for it in endurance and quiet pluck, and if you want to grumble, don't do it before the men. You and the engineer-in-charge must be in perfect accord, at least in appearance, if you want to further the interests of your employers and your own also. In setting up a transit on sideling ground it is generally better to put one leg of the tripod up hill and two down, but you must exercise a little common sense in the matter; try to keep the lower "parallel plate" as level as possible, as by so doing time in "leveling up" will be saved; try to make yourself master of your instrument as there is a great range in the value of transitmen, and try to "set up" each time a little quicker than before, and also a little better. The acme of setting a transit may be considered reached when one shove on each leg of the tripod brings the "plumb-bob" exactly over the point in the stake, while the instrument is found level "both ways." Try and see how many times you can do this every day, but don't waste time studying how to do it at each "set." It is rather better to keep the plates clamped together at zero, and do all lining of the instrument with the lower clamp and tangent;

take bearings on both fore and back sights as you may detect errors in reading angles by so doing, and be careful to record which way angles are turned. It is most convenient to run your transit ahead always and read the same end of the needle if the instrument is in as good adjustment as it should be. The stability of the adjustment differs very widely in different instruments. We have worked with an instrument for three months which never had to be touched, and also with another from the same maker which would not reverse truly for the day, although adjusted every morning; it becomes necessary, therefore, to learn the peculiarities of your instrument, and know, not guess at, its condition at all times. The reversal should be tested each morning before going to work until you are sure of the instrument. Learn which way to get the slack of the tangent screws, and to do good work with a poor transit.

THE LEVELER.

The leveler on a preliminary survey may have to work at his best to keep up with the transit party, and as the leveler and rodman have to work completely in unison, we will give them our advice together after their field work. Of course, in the office, or in camp they are two very different people, the leveler being one of the commissioned officers of the party, if we may use a military term, while the rodman is about the grade of a sergeant only. Still there should be very little difference of feeling between them. The leveler keeps all field notes and the rodman should also carry a book and keep the turning point sights and work out all heights of the instrument and elevations of turning points and benches in the field. Readings for turning points and benches may be taken to the thousandths, but for station heights the nearest tenth only should be read.

LEVELING.

Make all the vertical height you can in going up or down hill as you may save a setting thereby. Study the ground as to what is coming ahead and never select turning points or set up the instrument without having fully considered what is to be done next.

Be sure of the adjustments of the instrument and that the rod is held "plumb" (if the cross hairs are right, the man at the instru-

ment can see by the vertical hair if the rod is "plumb" one way, and by gently swinging the rod in the plane of the instrument after setting the target if the target rises above the hair, the rod was not held "plumb;" if the target on swinging the rod, falls below and just comes up to the hair, the rod has been held vertically). Make your signals with some system, and move the rod according to the signal in amount of motion as well as direction, speak your numbers distinctly and don't mistake the word seven for eleven, or the reverse.

Leveling can be hurried in open country by employing two rodmen and rods, and running them alternately, the employment of a fourth man to keep notes in such case being a great help, although such great haste is not often required or desirable.

Put in benches at least once in 1,500 feet in open country, and every 1,000 feet in rough country, as it may save you a good deal of work; select good points for benches and turning points, and always be sure that the instrument may be moved before you move it, and that you can find at least half of the turning points in the day's work.

In running "check levels" check up the benches every mile, and if the agreement is within one-tenth, call bench right and go on. Try to keep the check levels within two miles of each other, as it may save a good deal of annoyance.

The work of the rest of the party is much the same for location and preliminary surveys, and will be described further on. The engineer in charge of the party and the transitman are the ones whose work is increased the most, and their duties will be described again for location survey.

THE HEAD CHAINMAN.

The head chainman holds an important position and must be a man with sound judgment, and must understand his work. He should hold the transit rod with one hand, and the chain with the other, showing discretion as to holding the chain level and taking short lengths on hilly ground; he should understand the signals of the transitman and obey them intelligently; should have a good eye for line and use it every time he holds his rod up, so as to be as nearly right as may be before the transitman begins to signal to him; and he should always look at the transitman when lining, instead of gazing around at other things. His work is perhaps best conducted in the following order: When the chain is pulled out

he turns around, and holding the rod with one hand, tries to place it as nearly correct as he can by lining over the last stake to the instrument, while with the other hand he is trying to "straighten out the chain;" he then moves the rod in obedience to the motions of the man at the instrument, and after getting the line, holds the chain up to the rod with both hands and gets the distance; then dropping the chain he stands up straight, plumbs the rod carefully and receives the line again; then pressing the rod into the ground he makes the hole with the point, and takes it off the ground: a stake is then driven and the measurement should be repeated to see if the distance is correct, after which the rod is held on the stake "for line," the chain is then dragged on and the operation repeated. Time may be lost by neglecting the order of operations given above, or by not looking to see where the line is, and leaving all the movements to be signalled from the instrument, or by jerking the chain while trying to straighten it, or by not watching the transitman closely, and thus missing his signals. If you are so far away that the motion cannot be seen, take your handkerchief or hat and make a signal (imitating the lining signals) and the transitman will understand that you wish him to take his handkerchief, (when snow is on the ground, his hat) to increase the visibility of his signal. Remember that the transitman can see you plainly, and can guess what you may wish him to do. When you wish him to line you hold up your rod and wave it to catch his eye, and when you are sure that the line can go no further without a change in the position of the instrument, you must call his attention by holding your rod in both hands horizontally above your head; then after carefully lining and centering, you can call him up by beckoning with both hands, holding the rod above your head or by any other previously arranged signal.

SELECTION OF TRANSIT POINTS.

By far the most important duty in point of difficulty, is the selection of the transit points, which must be so chosen that the greatest distance ahead may be seen from them; in general they should be on the upper edges of hills, where a view of the valley on both slopes can be obtained, and if possible, where a full view of the transit rod can be had, as it is only allowable in case of necessity to sight at but a small part of the rod, and therefore great care must be taken to hold "plumb" at all times, as you do not know just how much of the rod may be observed. You must exercise consid-

erable judgment in the matter, and never be astonished if your views and the transitman's differ on this point. And here let us say a word to all the men; remember that the transitman has to work all the time, and that he has to take all the blame from the engineer-in-charge for all mistakes, and that if he does scold you for things that are not your fault, just wait till the matter developes, but do not try to argue during working hours about the work; if you have been to blame, you deserve "jawing," and if you have not, it will not hurt you a bit in the eyes of anybody whose opinion is worth having. The same remarks will apply to the transitmen and levelers in their relations to their superior; let them remember that the engineer-in-charge has more things to think about in a day than they have in a week, and if they don't believe it, wait until they have the same position and can see for themselves.

THE REAR CHAINMAN.

The work of the rear chainman is to hold the chain while it is being pulled along; we say hold it, for if you let the end go you may have to call the front chainman back for 10 or 20 feet after he has passed his proper distance, and he won't like that. Don't hang on the chain and be dragged by it, but be ready to give it a shake and clear it if it catches on brush or rocks. The rear chainman is responsible for the numbering of the stakes, and for all distances with "plus" numbers; he must be careful to assist in straightening the chain, to be on hand promptly in measuring, and not get in the line nor walk on the line, and not to jerk the front chainman's arms off by suddenly stopping. The keeping of the numbers right is a more difficult task than it seems to be, and requires a good memory; in all cases of doubt, go back and find out at the last stake what is right and don't guess at it. Be careful that the chain is in good order—that the links are straight and that the rings are not pulled open. Do it up from the handle and keep the strap around it; learn to throw a chain over a stream; one end of an ordinary heavy chain can be thrown over a 50 feet stream. And by making two bundles with say 15 feet between them, and using two men to throw, one after the other (at say half a second interval), we have thrown the end of a heavy chain 75 feet. Be careful that the chain is not dragged against the transit legs, and do not hit them while trying to stand the straightening as inflicted by the head chainman; be prompt to assist in making short chains on hilly ground, and on curves, if there are any, and walk the outer side

of the line lest you get in the "line" of the instrument without knowing it.

THE AXEMEN.

The axemen are under the general direction of the head chainman who gives the line for cutting brush and timber with his rod. One axeman must be in charge of the stakes and must never let the chain work wait for him a second, but must keep up at all risk. Sometimes a large basket is useful in carrying stakes. The stakes should be numbered by the chainman, and if he marks a number of them in the basket, care must be taken to see that in "plus" stations the numbered stakes are not used, or the numbers may get "mixed."

LOCATION.

In location surveys the only difference in the work of the men is in the curve work, where the head chainman has to offset from the line of the last stake to find the transit "line" by an amount known as the chord "deflection," for which see "Henck's Field Book." We always gave the chainman a list of "chord deflections" for the even degrees, and let him guess at the amount of the ground, and found that it saved time. The centering of the stakes should be attended to a little more carefully than on preliminary work, and the measurements made with more care.

A back rodman will be necessary, and we can only caution him to stand up, with his rod in position all the time, or if near enough to see, whenever the transitman turns over his telescope, he must be on hand. Although the job is not very interesting it is important. We used to let the back rodman carry the coats, and if we took our dinner along, a basket with the "grub."

Each man in the party must be held strictly responsible for what tools or instruments are put into his hands, and a careful property account must be kept and reported from time to time.

WASTEFULNESS OF CARELESS LOCATION.

Location surveys differ from preliminary surveys in being more carefully carried out, as to the exact position of the line, and in the curve running, which is usually omitted on the preliminary work. The exact position of the line is a matter of great importance, for many dollars are thrown away by careless locations and in many cases the theory of wilful ignorance is the only excuse that can be

made for them. There are needed careful judgment, long experience, and a great deal of real hard work on the part of the engineer in charge of the locating party, to make successful locations.

THE TOPOGRAPHER.

The party is usually organized with the same force as in the preliminary survey, viz: An engineer-in-charge, transitman, leveler, level rodman, two chainmen and from one to five axemen. To these are often added a topographer, and sometimes a cross-section leveler and helper or rodman. The topographer takes sketch-notes of the contours and surrounding country, roads, buildings etc., which have to be shown in the plans, and if he carries a pocket "azimuth compass," or a pocket sextant, he will find it a great help to him, but for his work we especially recommend a small plane table, 18 inches square, with the paper on it in "block" fashion, the board fitted with a shoulder strap, and Jacob staff mountings, and a folding "alidade" or ruler, with sights. With this outfit a topographer can produce a line map which will make his chief engineer's heart glad, and which will go a long way towards convincing the directors that the party have done a lot of work. The use of the plane table for this purpose is not common, but such an arrangement costs very little, and nothing else will show as much of the country in a very short time. The field use of the instrument is very simple; the line already run being platted before taking the field, the "orientation" can be performed from stakes and it can be used anywhere.

The cross-section leveling is only performed in very rough country; a 10-foot pole with a short spirit level placed on it, and then held with one end on the ground and the other against a graduated rod on which the rise or fall in 10 feet is noted, is used; the information obtained in this way is very considerable; there is a good deal of work to get it but the men are not required to have a very high grade of mental organization and do not draw a very high pay.

ENGINEER IN CHARGE.

All of the increased care and skill required and already mentioned has to come from two men—the engineer-in-charge and the transitman—the former has all the responsibility of the added importance of the survey, and the constant study of the ever changing ground, and the greater or less difficulty of the work itself: and

the latter has all the curve work, with increased watchfulness and greater accuracy, to attend to; those two men have their work nearly doubled, while the work of the rest of the party is only increased by the additional care and attention which has to be enforced on all the party.

To the engineer-in-charge we shall say very little, and to a man in that position little can be said—if he does not know his business he certainly ought not to be in the place, and if he does know it, our advice is unnecessary, yet if he does not think it beneath him to read what we have to say to transitmen, he may here and there find a hint to help him in watching the work of that indispensable assistant. And here let us say that no money is ever sa ed by making the engineer-in-charge of the location run either transit or level, as he needs all of his faculties to be at all times sharpened to their utmost degree to attend to his own duties, and if the tedious instrumental work is put upon him he cannot keep everything going at once properly. And let us say also, that if the engineer-in-charge wishes to make every man do his very utmost, that he had better take the head of the chain himself when he can spare the time, especially on long tangents, which he has already determined. By so doing he will be near all the men of the transit party, and they will work when they are right under the eye of the "boss," and he will be sure that no time will be lost in picking out the transit stations, and that the stakes are kept well up; the transitman will always hurry up to him, and if he cannot keep them all "on the jump," he is not fit for his place. Of course, he has frequently to go ahead and pick out the ground, and go back to see how the profile will plat, and tell the transitman what must be done in his absence, and in this he must be his own judge of his time and of its disposition, but still, when he wishes to drive matters, he can do so best from the head of the chain, in the meantime letting the head chainman take the transit rod and keep up the centers; the mental work which he has to perform all the time will not suffer from the mere manual labor of being head chainman.

KEEPING TRANSIT NOTES.

The transitman has after all a hard place to fill, for there is no variety in his mental work; he has to keep a sharp watch on the men when his superior is absent, and has the constant computation of deflection angles to attend to on curves, at the same time

using all possible diligence as to figures. And here a hint as to the easiest way of keeping the curve notes and doing the transit work. The method originated we know not how, and may have have been used by large numbers of transitmen, although we have never happened to meet them.

The basis of all circular curve work with the transit is the well known theroem: the angle between a tangent chord, or between any two chords which meet at a point on the curve, is measured by half the intercepted arc. And as the point where the chords meet on the curve may be anywhere on that curve, it follows that the sum of any consecutive angles or series of angles is the same no matter where the instrument be placed on the curve for given arcs, and that if the deflection angles be all computed from the B. C., as far as may be desired, at any station on the curve the number can be used, as the differences will be the same for the same stations. To illustrate this, we must assume an example.

Let it be required to run a five degree curve from sta. 131 + 40, and let us first look at a page in a field book:

STATIONS.	DEFLECTIONS.	CURVE.	TRUE COURSE.	NEEDLE COURSE.
129			N 16¼° W	N 16° W
130				
B. C. +40	0°0′	5°R.	N 16°15′ W	
2	1°30′			
3	4°0′			
4	6°30′			
5	9°0′			
+50	10°15′			
6	11°30′			
7	14°0′			
8	16°30′			
E. C. +25	17°7½	34°15′	N 18° 0′ E	N 17¾° E

We see the book is ruled with five columns and usually on the left hand page, the right hand page being reserved for "remarks." The column for Stations explains itself, the signs "plus" being used, decimal points for a hundred foot unit, and the ordinary "decimal" being reserved for feet and fractions of feet. The letters B. C. and E. C. are used for beginning and end of the curve, instead of the P. C. and P. T. used often for "point of curve" and "point of tangent," being more in accordance with the usage of ordinary geometry and has been our custom for several years.

The column of deflections contains the deflection angles computed from B. C. as far as convenient, say to station 135, and the stakes set and centered, for same reason 135 + 50 becomes necessary and has to be put in; then the transit is turned back to 0° and turned over on the back sight to be sure that nothing has slipped and carried up to 135+50, and set up. The instrument is then set at 0° and sighted at B. C. and then if turned to 10° 15′ it would be on the tangent at 135 + 50, and if turned to 11° 30′, it will be on the chord from 135 + 50 to 136, and by adding these 2° 30′ for each hundred feet the curve is run to 138 and the transit is moved to that place after taking a back sight as before, with the plates at 0°. After setting up at 138 if we could see B. C. we should set at 0° again, and turning to 16° 30′ we would be on the tangent; but B. C. is supposed invisible, and we shall therefore set the instrument at 10° 15′ and sight it back at 135 + 50 and the result is that the lower plate is in the same position as if B. C. had been visible, and we had as above suggested set 0° and sighted thereat; by turning to 16° 30′ we shall be on the tangent at 130 and if we find that 1° 20′ more will be needed to strike the desired direction from there, we will put 1° 15′ more in the curve or 37½′ deflection which corresponds to 25 feet; we run out the 25 feet and turn to 10½′ and sight the stake in, and then turning to 10° 15′, we turn over to the back sight; after satisfying ourselves that it is all right, we go to 138 + 25 and being sure the instrument reads 10° 15, we sight again at 135 + 50 and turn to 17° 7½′ and are at the tangent. By taking the differences and comparing distances it will easily be seen that the angles are all right.

Now in what does this method consist that is better than the practice of counting stations and multiplying by the deflection angle? Only this, that the counting and multiplication are both performed already. Each station is attached to the angle opposite to it in the note book, and once there it is good for all the work that you can do with it. The mental labor thus saved is a great help. It was once our fortune to have to "break in" two "green" transitmen in five weeks, and in all that time we computed every angle that was used at the instrument, mentally, and kept at the head of the chain most of the time; by asking the man at the instrument what reading he had and what station he was at and what his back rodman was at, we never let a mistake pass our notice. (*Note.*—We are not anxious to repeat this experience of our transit running from the head of the chain.)

For the transitman himself this system of notes is a great relief as he is free from the constantly recurring question "what is your next deflection?" with its importunate worrying when he has just set up on an odd "plus" and knows that his back rodman is also on an odd "plus," he simply asks himself, what are the readings for these two stations knowing that the difference between them has been computed carefully once as they come along, and it will be all right now.

COMPOUND CURVES.

On compound curves the same method can be followed all around, but the back rodman and the instrument must be on the same branch (the P. C. C., point of compounding of curve, is of course on both branches). The next column of the note book is headed "curves" and in it are recorded the degree and direction of the curves and the central angle, or angle of intersection; it is twice the last deflection angle always. In the next column is put up the computed courses from the first one, and the next one contains the needle readings; the use of these is a check to the transitman's work and sudden variations are not common. If "local attraction" exist, it can be found by reading the compass at each end of the tangent. We remember a local attraction which bothered us all one morning and which never seemed to be the same for two minutes running, and which quite frightened our "boss" but as we were within fifty feet of a north and south track, we talked "earth currents" at him (they were east and west) and as we were sure of our work we let it go unexplained; in the afternoon we discovered the innocent cause to be a small "Smith & Wesson" in our overcoat breast pocket, and we have never seen any such local attraction since.

LONG TANGENTS.

Long straight lines require a good deal of care, and the instrument should be reversed "both ways" on them, and if a long sight can be obtained backward so as to overlook two or three transit points, they should be tested by the direct instrument. If great care is needed, the instrument should be used "both ways" without reversing, and the slack of the clamp screws watched. Tangent screws are now so generally made double that the play of the motion screws can be prevented from interfering with the ac-

curacy of the work, but the clamps will wear loose a little and must be watched.

LAND LINES.

In Railway field work, after the location survey, follows legitimately the land survey or "land lines" as they are called in the east, and although most of this work is included in common surveying, yet there are some points of difference which it will be well to touch upon. In cities and towns where land is valuable, it is of course quite important to have the work done accurately; and although in the western country, where the land is very commonly given to the railroad company it is not so essential, still it is always desirable to know how to do good work, and a few words as to general surveying will scarcely be out of place.

In the first place be sure that your work is definitely connected with points which can be found again, and that the connection with the main line is right, and that it is simple; any complex measurement is to be avoided. In the next place, measure every distance pertinent to the work which can be directly measured. Calculate as little as possible. If the land to be taken is very irregular in form, a "traverse" is the best method of attack if all the sides can be measured; don't have any "omissions" to supply if you can help it; be careful to take all offsets at right angles; take the angles with a transit if one can be had, and do not use the compass in any way but as a check on the transit; for sighting right angles quickly, some of the forms of the "optical square" may be found very convenient; for ordinary work in cities most of the measurements for land will be at right angles or nearly so, and the work can be laid out on four lines forming a trapezium; do not trust to any building for a right angle or to any two walls of the same building to have parallel faces; brick laying is not by any means the most exact of trades, and although for a map the errors will not show, yet for other work to be connected to that in progress, it may lead to serious errors.

For railroad purposes the land is usually found in long narrow strips of varying width; and it is sufficient to find the length on the centre line, and directions of bounding lines which cross; it is however, desirable to have all "land lines" within four or five hundred feet of the track, and this requires measurements on the crossing lines. In getting the direction of a fence, when the instru-

ment is placed at one side, measure the distance from the instrument to the fence at right angles to it and have a similar "offset" made as far as possible from the instrument; of course the main line should have been run and the transit placed in the line before the direction can be obtained.

For street surveying the best method is that of a line in the middle, with offsets and measurements connecting, the offsets at the end as well as the line run. In very crowded streets we have sometimes run a line down each footwalk, connected them carefully at their ends, and then proceeded as described for a single line.

CAREFUL NOTES

In all work of this kind the most important thing is to take good notes; always put these down as if you expected to die before morning, and wanted to leave them in such good condition that in ten years time a stranger with no previous acquaintance, and with no one of the old party to help him, could take your book and proceed on the job without delay; if this can be done, your notes must be about right, but you never will have them too complete. We have never used any but the "sketch system" for taking notes, and we always made them in the field, and copied them over on the next page in ink, thus keeping the rough set with the original figures, and the finished set to explain them; the original figures have more weight as evidence, but the explanation given by a neat ink copy is a very great help in interpreting them. For city work take all angles with the transit more than once, that is to say, "repeat them," three or four times which is enough; the object of the "repeating" being to check the angle and not to subdivide the vernier reading.

PRESERVING THE LINES

After the completion of the land survey comes the actual field work preparatory to the construction, and here it is customary to reduce the number of men in the party and to begin to "cut down expenses" in the engineering department.

The first thing to be done is to "preserve" the line, that is, to connect all tangent points with stakes that are away from the line and far enough from it not to be disturbed by the operations of grading and earthwork; at the same time the slope stakes should be set and marked with the cut and fill—also the cut or fill should be marked on the centre stakes—this work can all be done on the same job, and

thus the contractors can make a start at once if they so wish; of course a record of all field work is required, and the results should all be put in the grade book. For setting slope stakes the only satisfactory method is with the Leveling instrument, though for comparatively smooth ground and light work, there are various devices for setting slopes which involve much less work, and are sufficiently accurate for use.

CENTRES AND GRADES.

Most of the work for railroads in construction consists in setting "centres" and "grades;" for the former, in nine cases out of ten, the line can be run in without an instrument, if the known points are convenient; the Tangent Deflections are useful for running curves with only the chain and rods for lining; for approximation there is a very convenient method of computing angles and distances (measured as arcs) which it is well to be familiar with in the absence of all "pocket-books." At one hundred feet distance three-hundredths of one foot subtends one minute of arc. Strictly speaking it is twenty-nine one thousandths instead of three one hundredths. At the same distance one foot and three-quarters subtends one degree of arc, but one and eight-tenths can generally be used. With this once fixed firmly in the mind, mental computations can be made with the greatest ease. As an example of this let it be required to find Tangent and Chord Deflection for 100 feet chord, and for 60 feet chord, and ordinate at centre of 100 feet chord for a 5° curve: $5\times1.8=9.00°$ for the Chord Deflection, and 4.5′ for the Tangent Deflection 100 feet chord: $4.5\times0.6=2.7'$—$2.7\times0.6.=1.62$ Tangent Deflection for the 60 feet chord, and $\frac{1}{4}$ of the Tangent Deflection for 100 feet chord $=1\frac{1}{8}'$ for the middle ordinate. These values are all in excess, and if the deflections are to be used for running the curve more than one station, the value $1\frac{3}{4}'\times5=8\frac{3}{4}'$ should be used, and this is in error only about $\frac{3}{8}$ of an inch. A great many other computations may be thus performed mentally, and the work already done checked by these approximations, and the real blunders found.

QUALIFICATIONS FOR LEADER.

There are many ways of doing most kinds of field work, and many methods are described in the books under various heads—but a good knowledge of geometry and trigonometry, and possibly a little familiarity with analytic geometry, combined with a cool head, and an appreciation of the external circumstances, will en-

able a man, after a limited experience, to become competent to take charge of a party in the field, as far as the mere theory of the operations is concerned—but a knowledge of human nature and sound judgment are required to give satisfactory results.

CULVERTS AND MASONRY.

We would say a word about the staking out of culverts and masonry, and will begin with a hint about box culverts. On masonry of this class it is well to put in four stakes on the lines of the face of each wall, one at each end of each line, and two stakes, one on each end of a line terminating the culvert at the proper distance out, found as in slope stakes. These stakes must all be placed outside of the trenches, and should be at such a distance from the work that they will be safe during the construction.

BRIDGE ABUTMENTS.

Bridge abutments on shore can be given in the same way, and if in the water by parallel lines, or sighting frames made out of strips of wood. Piers can be located by sights on shore, or as they are commonly termed "ranges."

EARTHWORK MEASUREMENT.

If earthwork is to be measured in a "borrow pit," the best way is to run out two sets of lines at right angles over the ground, denoting distances in one direction by letters, and in the other direction by numbers, and taking the levels all over the ground denoting the stake by both letter and number, and then every month as the work is done, these stakes can be replaced and the levels taken again. The bounding lines of this system should be carefully put in, and the stakes may have permanent "sights" put up over them; in this case the stakes of the system can be replaced without a transit. Of course the bounding lines should be wholly outside the work and there can be little trouble in taking care of the work in this way.

RETAINING WALLS.

Retaining walls are very usually set out by stakes, but "sighting frames" outside the wall and in line with it are to be prepared, if the height is not too great.

TUNNELS.

Underground work in tunnels is usually kept in line and grade by points on the roof; their stability and permanence are much greater than if given on the bottom of the tunnel. In rock work where stakes can not be used, chisel marks are made to serve as points. Such work requires less frequent attention, but is more important.

RESPONSIBILITY OF ENGINEER.

And now in closing, let us add a word as to the responsibility resting upon the engineer when setting out work.

Few beginners appreciate the necessity for correct work, and do not realize that a blunder undetected may cause a loss to the contractor of a great deal of money, and that if he, as the company's authorized agent, makes a mistake in his work, the company may become liable for many times his salary, and that his discharge is a very small amelioration of matters which he has mixed. Pecuniary responsibility must be fully appreciated in order to have accurate work done.

Mistakes in work are not only discreditable but they are dishonorable, and to the feelings of the suffering party they seem criminal. Now as man is liable to error, work must always be in some way checked, and a mistake which is discovered by the maker in time to be rectified by him before any damage is done is in no way discreditable, provided however that it does not happen too often, and that the same class of mistake is not made the second time. Nothing gives a contractor less respect for the engineer than finding his mistakes, even if they have caused no damage.

—o—

STAKING OUT.

"What is that, mother?"

"The Rodman, my child.
His footsteps are weary, his accents are wild;
His hair, how disordered! his eyeballs, how blear!
And see where his necktie hangs under his ear."

"Rod up there! Hold her steady! ! Go on down the hill ! ! !
7.8. Cut 2.2—No, begosh it's a fill,
Half the roadbed; 13 + the slope 1.1;
No, it's 1½ though, as sure as a gun.
Well, that makes—let's see—O! stick her in there.
It'll do. Perhaps the contractor will swear.
But no difference: We're the big dog in this fight.
No matter what's wrong, just swear it's all right.
A contractor don't know a beefsteak from a bone.
Now pick up your tools, and let's pull out for home."

J. H. K. B.,
Laurel Hill Swamp Angel.

—From the *S. P. R. R. Transit.*

CHAPTER III.

REGULATIONS FOR THE ENGINEERING DEPARTMENT DURING CONSTRUCTION.*

BY WM. F. SHUNK, C. E.

I. ORGANIZATION.

1. The chief engineer will have exclusive control of this department.

2. He may be aided by a consulting engineer, without executive powers, and an associate engineer, acting under his immediate direction, to whom all official communications from subordinates should be addressed, and whose orders concerning the work, or matters thereto appertaining, shall be received as authoritative.

3. The associate engineer shall be aided by such a staff of division engineers, principal assistant engineers, draughtsmen, clerks, and other helpers as shall be approved by the chief engineer.

4. Each division engineer shall have charge of the construction of about thirty miles of road, in sections approximating one mile long and subdivisions composed of from six to ten sections.

5. Principal assistant engineers may be appointed to special charges, such as important structures, the compilation of records, the preparation of plans and the like. Where such charges fall within the territorial limits of a division engineer, strict definition of responsibility will be made and hearty co-operation expected.

* South Pennsylvania R.R.

6. Division engineers shall have power to employ one draughtsman for the division headquarters office, and such resident engineer, inspectors, time keepers, and other helpers on the line of road as may be necessary for the proper conduct of the work for which they are immediately responsible, subject beforehand to the approval of the associate engineer; and to suspend or discharge such employés for sufficient cause. The power of removal should be exercised discreetly, and seldom without reference to the associate engineer.

7. Each resident engineer shall be aided by one rodman, competent to use transit and level, two tapemen, and one axeman. until the line is cross sectioned. Thereafter one tapeman may be dispensed with. Special assignments of force will be made, when necessary, to divisions which include large tunnels. Each resident engineer shall have power to appoint, suspend or remove his own subordinates, subject to the approval of the division engineer.

8. Good discipline and orderly management require that all official communications, verbal or written, shall pass from the superior to his immediate subordinate, or from the subordinate to his immediate superior. Should any emergency necessitate a deviation from this rule, the party intermediately concerned should be informed of it.

II. PREPARATORY WORK.

1. First of all, division engineers shall cause the centre line of location on their respective divisions to be accurately retraced. established and test leveled.

2. This done, they shall furnish promptly to the associate engineer a map in duplicate of their respective divisions, scale four hundred feet to an inch, one copy to be on mounted drawing paper, the other on tracing linen, showing the centre line and proposed right-of-way boundaries in red; intersected and adjacent property lines with names of owners, political boundaries, contours, streams, roads, woodland, buildings, and other objects proper to a working map, in black; also a profile, similarly duplicated, to "Plate A" scale, upon which shall be marked the estimated quantities in each cut and fill, the character of the material, the alignment corresponding to map, and the proposed grade line, the latter to be penciled on the paper duplicate and drawn very finely on the tracing in red, with its rates per centum and elevations of change points clearly figured.

3. The paper copy of each of said duplicates will be returned, with

such alterations as the chief engineer may think proper to make or approve, and endorsed with his approval, or that of his associate, to the division engineer, who shall place them on file in his office.

4. Thereafter no change of line or grade will be permitted, excepting upon compliance with the like form of procedure, namely: The submission of duplicate drawings of the change proposed, and the return of copies approved by the chief engineer or his associate.

5. Division engineers shall cause to be prepared for each of their Residents copies, from the foregoing approved map and profile, of the respective subdivisions, and also a pencil record of location, in the following form, to be called the "*Location Record, Div. No. . . Subdiv.' No. . :*

Sta.	Deflec.	Align-ment.	Mag. Course.	Gradient.	ELEVATION.		Cross Sections.	Remarks.
					Ground.	Grade.		

6. In the station column, transit points should be marked with a circle. as usual, and turning points inclosed with a triangle in addition to the circle. Directly below every turning point record the note should be made, "B. S. to . . . ." indicating the backsight point; and in the deflection column should be recorded the total deflection, at each turning point, from the range of backsight to that of foresight. By means of such a record the line can in future be retraced, not only over the same points, but, failing one or more of them, with the same angles used on the establishment of location.

7. The alignment column must show the calculated course and the length of each tangent, thus; N. 64° 35′. W.—3,972 feet; and the degree, length, angle, and apex distance of each curve, thus: 5° C. R. (or L.)—650 ft.; angle, 32° 30′; A. D. 334 feet.

8. The column of remarks should contain notes of benches, land, stream, timber, and road lines, and other matters of interest relating to the line or the work to be constructed. The cross-section columns should be reserved. Stations should be entered on every third line of the book only, thereby recording about eight hundred feet per page, to provide for subsequent additions.

9. The original book from which the copies are made, should be retained by the division engineer.

III. RIGHT OF WAY.

1. Division engineers shall next cause the necessary surveys for right-of-way to be made, and maps thereof to be prepared on "Topography" paper, scale two hundred feet to an inch, showing the plan of land to be taken, the contents of severalties in acres and hundredths, the Township, County and State wherein situated, owners' names, road crossings, streams, buildings, woodland, meridian line, and other objects needful or useful in such an exhibit.

2. These maps shall be consecutively numbered, and shall have a blank margin two inches wide on the left edge, that they may be bound in volumes for the Company's archives. When more than one property is represented on a sheet, the severalties shall be designated by the sheet number and an annex letter, "*a*," "*b*," etc.

3. Division engineers shall furnish to the land agent appointed by the Company, when requested by him, a tracing from these maps numbered and sub-lettered to correspond with the original, together with a description of each property, for incorporation with the deeds.

4. Currently with the purchase of right-of-way, or as soon thereafter as more important service shall permit, division engineers shall cause the boundaries of the Company's property to be marked by corner and line stones, or other endurable monuments. This should be done before ground is broken, if possible, and said monuments should be carefully maintained during the progress of construction.

5. Division engineers, in laying out proposed land purchases on the maps, prescribed in (II., 2,) should provide amply for station grounds extra tracks, borrow pits, and spoil banks, and call attention thereto by explanatory notes on said maps.

6. The lay-out shall be for a double-track railroad, tracks thirteen feet between centres. Sixty feet shall be the minimum width taken in any case, without the express approval of the chief engineer or his associate; and as a general rule, a berm twelve feet wide on each side of the road formation shall be included in the Company's right-of-way.

7. The Company's boundary line shall generally be parallel to the centre line of the railroad, and right-of-way widths shall change by jogs square to said centre line, excepting at the bounds of severalties, where changes of width should be located, whenever convenient, and conformably to existing land lines.

IV. FINAL PREPARATIONS FOR CONSTRUCTION.

1. The centre line having been established and test-leveled, agreeably to (II., 1,) it should now be gone over with the level very carefully, setting stakes at "grade" points and at changes of surface necessitating additional cross-sections, marking the variations on the backs of centre stakes, noting the elevations of roads, stream beds and high water lines, and making new bench marks at intervals of about one thousand feet, preferably near the sites of structures and heavy cuts, where most needed, and out of the way of probable disturbance.

2. Then traverse the line again with the transit, over the old points and with the same deflections recorded on the establishment of the location if found correct, trueing the interpolated stakes last set by level, and placing and referencing centre plugs at "grade" points, grade summits, and wherever else they are likely to be convenient during construction.

3. Any discrepancies in line or level with former work, discovered during these operations, should be reported immediately to the division engineer.

4. Slope staking follows next in order. Division engineers shall personally ascertain the probable character of the material in excavations, boring or sinking test pits when, in their judgment, the importance of such knowledge warrants it; and they will instruct their subordinates as to the formation slopes to be adopted in every questionable case.

5. In addition to setting the usual grade and slope stakes, the ground should be cross-sectioned a sufficient width to provide for possible slips, further changes of slope, or a four-track road. Stakes or plugs should be firmly driven at these limit points of observation, whether the work be in cut or fill, in range crosswise with the centre and slope stakes, which should always be placed at right angles to the road axis, their distance from centre line and elevations as to grade being noted for record, and for use if needed subsequently. They may prove to be very convenient during construction at cuts through uncertain material, and when measuring for estimates.

6. On hillsides where the road bed is partly in excavation and partly in embankment, its dimensions shall be compounded of those given in the standard drawings for excavation and embankment.

7. Borrow pits, grading at stations, ditches, and all other incidental

excavations, should be staked and recorded with the same exactness as the road formation. They should be worked in a regular manner, so as to be readily measured, and present a shapely appearance after completion.

8. Masses of rock found in cuts and isolated from the slopes should be measured and recorded in the proper books and shown in the cross-section drawings.

9. The accurate establishment and subsequent protection of tunnel lines should claim the early personal attention of division engineers. They will be duly authorized by the chief engineer to acquire the temporary use of ground for observatories and guide lines outside the Company's right-of-way, when expedient to do so.

10. The alignment and levels at tunnel sites should be retraced and repeated until the possibility of error is reduced to an unimportant minimum. Such work is best done early in the day, while the air is equable and free from refractory currents.

11. Resident engineers shall personally attend to the staking of all foundation pits. Before masonry is started, the division engineer should inspect such pits, and assure himself by sounding or otherwise, that they are of sufficient depth and firmness. When judged prudent, the bottom earth should be compacted with rammers.

12. Currently with the foregoing operations, the location record, prescribed in (II., 5,) should be perfected by the addition of the cross-section notes, and the latter line and level notes, and all permanently entered in ink.

13. Division engineers should traverse their charges weekly. Resident engineers should be constantly on the line by day, excepting when foul weather or important office work prevents. They should give grade and line weekly, and whenever asked by contractors. They are thus in the way of correcting errors at the outset, of instructing foremen seasonably to prevent errors, and of ascertaining the various character of material for estimates, to the furtherance of the work and the due service of the contractors, who should not have reasonable ground for dissatisfaction with this department.

V. STRUCTURE PLANS.

1. The chief engineer will cause standard drawings of the road formation and ordinary structures to be furnished to each division office. Di-

vision engineers shall supply duplicates of these drawings to their resident engineers, as needed.

2. Division engineers shall cause necessary modifications to be made in masonry plans to adapt them to various localities, altering the flare or length of wing wall, for example, to fit irregular ground, skewing for oblique channels or roads, sizing for heights intermediate to those provided for in the standards, and the like; but the elevations and square widths of bridge seats shall not be altered except by warrant from the chief engineer or his associate.

3. Special instructions will be given as to structures on steep inclines and skew openings sharper than forty-five degrees from the centre line.

4. Plans modified by division engineers, and also the standard structures which they propose as being anywhere suitable, shall have the approval of the chief engineer or his associate before the work is laid out.

5. Where special structures are required, such as viaducts, large bridges, or other exceptional work, not provided for in the standard plans, the division engineer shall cause the ground to be surveyed and mapped to five feet contours; scale, ten feet to an inch, with corresponding profile, and submit the same, accompanied by illustrative notes and such suggestions as he may think proper to add, to the associate engineer, who will, thereupon, cause a plan to be made, or give orders for its making to the division engineer. Exhibits of this kind should include high and low water marks, character of bottom or sub-soil, and, in the cases of road-crossings, a profile of the same for five hundred feet each way.

6. All plans of railroad buildings shall originate at the central office, and copies thereof will be furnished by the chief engineer or his associate, with suitable instructions, to the division or principal assistant engineer charged with their erection.

7. Copies of all plans prepared by division engineers for their residents shall be preserved in the division office.

VI. FIELD AND OFFICE RECORDS.

1. Resident engineers shall prepare a series of cross-section drawings, including the tunnels, of their respective subdivisions, in bound books of uniform size furnished for that purpose, showing the original surface of

the ground as widely as observations extend, the slope staking for road formation, the staking for incidental excavations, the proposed formation lines, and the computed quantities before grading, in India ink; copies, or written abstracts, of which cross-sections they shall transmit to the division engineer from time to time as they are made, marked with the name of the division and other distinguishing particulars.

2. On completion of each road-section the resident engineer shall amend and perfect his original cross-section book by drawing thereon, in permanent red, the actual formation as completed, showing the parting lines between various classes of material, and the actual quantities of said various classes as contained in the final estimate of the graduation of said road-section; together with a statement of the cost of said graduation to the contractors and the Company, which amendments the division engineer shall thereupon cause to be incorporated in his own copies of the cross-sections, after revision by him, and shall, when requested, or on the completion of the work, transmit the originals to the associate engineer, endorsed with his approval.

3. The statement of cost to the contractor should comprise, as nearly as can be ascertained, the value per item, and the amount of labor, material, use of tools and machinery, superintendence and sundries, distributed and assigned in such detail as information on hand shall warrant. The statement of cost to the Company should be a summary of the final estimate.

4. The cross-section books will be paged with consecutive numbers; no erasures shall be made in them, nor shall any leaf be removed therefrom for any cause whatsoever. If errors occur cancel the page in such manner as not to obscure the errors, and use the next page.

5. Resident engineers shall also prepare a series of masonry drawings, on white paper sheets of uniform size furnished for the purpose, in which all such structures, including drain pipes, shall be represented on a scale of four feet to the inch, or eight feet to the inch, as the division engineer may prescribe for structures of various magnitude. Such drawings shall show the said structures in plan, elevation, and section as actually built, inclusive of foundations, foundation pits, substructure if any, grade line, and elevations of leading details. There shall be also a legend on the drawings of each separate structure, stating clearly the actual quantities of the various classes of work included in the final estimate, and a summary, such as is prescribed for graduation, of the actual cost to the contractors and to the Company.

6. On the completion of each subdivision said cross-section, tunnel and masonry drawings shall be transmitted to the division engineer, and by him, when so requested, after correction therefrom of the copies on his files, transmitted, with his approval affixed, to the associate engineer.

7. Each drawing of the two sets described above shall be exactly localized, in its title, with the name of the division, subdivison, section, station and plus.

8. Each division engineer, at or before the time of transmitting his first monthly estimate, shall send to the associate engineer a complete profile, on mounted "Plate A," paper, of his division, showing alignments, gradients, and other full details as finally established for construction.

9. Then, and thereafter with each monthly estimate, he shall forward to the associate engineer tracing exhibits, or written memoranda, indicating the condition of the work at the date of said estimate, from his progress profile, in order that the progress profile in the central office may be supplemented to match.

10. All progress profiles shall represent the work done during each month in transparent washes of color, as follows:

January.....*Carmine.*	July,.....*Scarlet.*
February .....*Green.*	August.....*Dark Green.*
March.... .....*Yellow.*	September. .....*Orange.*
April..... .....*Cobalt Blue.*	October.....*Purple.*
May,.....*Burnt Sienna.*	November .....*Burnt Umber.*
June.....*Black.*	December.....*Gray.*

11. Division engineer shall cause to be prepared, on mounted white roll paper, a complete map and profile of his division, horizontal scale four hundred feet, vertical scale forty feet to an inch, both on the same sheet, showing the centre line, grade line, and land lines of the road in red, streams in blue, brick and frame buildings in carmine and burnt sienna respectively, faintly colored; all other details in India ink, with ten feet contours finely drawn, each even hundred slightly heavied, and the outer limits of road formation—that is to say, the crests of cuts and the toes of fills—indicated in plan by dotted lines. This document to lie on the stocks in the division office, gradually perfecting, and finally including all the company's lands and buildings, together with such supplemental plans, to larger scales, as the chief engineer shall order, of town properties or particular reaches of the road, whereupon it shall be filed

in the central office as a permanent record. The above map should embrace, if possible, all the topography obtained during the surveys within one mile on each side of the located line, and should be neatly and accurately executed.

12. Each division engineer, contemporaneously with the foregoing map and profile, shall cause to be prepared a complete record and description, by sections, of the finished roadway on his division, after the following general form, to be furnished from the central office:

Div. No....., *Sec. No.....*

Sta.	Dis.	Def.	Allign't.	M. C.	RT. OF WAY.		ELEVT.		Gradient.	Width of road-way.	CROSS SECTIONS.			GRADUATION C. Y.					
					L.	R.	Ground.	Grade.			L.	C.	R.	Rock.	Loose R.	Earth.	Embk.	Found.	Misc.

MASONRY CLASSES C. YDS.					DESCRIPTION OF			
1.	2.	3.	4.	Misc.	Mas'y structures.	Bridges and viaducts.	Miscell.	Remarks.

13. To the record of each road section shall be appended a summary or the final estimate for said section, as paid by the company, and the column of remarks shall contain the miscellaneous notes from office records previously compiled, together with such other information, as to boundary monuments or plusses, bench marks, foundations and sundries, as may be of use on future enlargements of the road-bed and right-of-way.

14. Division engineers shall require periodically from their subordinates the data necessary for the compilation of this record. On its completion they will entitle it, adding a brief description of the division, its locality and terminal points, and transmit the record to the associate engineer, endorsed with their approval, for the company's archives.

15. Resident engineers shall keep a series of field books, to be called "Construction Notes," one of which shall be always borne about them, and used for recording their daily doings, noted on the spot, with day, date, and locality specified. In these books all field operations relating to the work of the contractors shall be calculated and entered, such as the giving of line or grade, setting or re-setting cross-section stakes, laying

out tunnels and structures, measurements for estimate, dimensions and depths of foundation pits, coffer-dams, elevation of bridge seats, verbal orders given to the contractors or their agents; in short, all their transactions and observations on the line, together with a diary of office work. The current volume of this series should be delivered to the rodman for his use, if charged with separate field duties, in case of the absence or disability of the resident. These books will be numbered consecutively and plainly marked, on the outside, with the names of the division and subdivision, and the periods of time covered by them. They shall be preserved with great care, and turned in to the division engineer on the completion of the respective subdivisions, or when called for.

16. Resident engineers shall use and preserve bound books, to be furnished from the central office, instead of the common scratch-blocks, for office calculations, drafts of estimates, all figuring of exhibits or return called for by the division engineer, and statements by others entitled to them, with day and date noted at the time of each entry. These books shall be called "Blotters," and shall be numbered and marked as prescribed for "Construction Notes."

17. Division engineers shall keep similar books for the record of their daily doings in the office or field, and these, together with those of the resident engineers, shall be delivered by them to the associate engineer, on the completion of the work, or when called for. "Construction Notes" and "Blotters" shall be left in the original manuscript, and not inked over in pencil. If errors occur, cancel in such manner as to leave them legible, and insert the corrected work further on, noting the former as erroneous, and referring to the latter.

18. Division, principal assistant and resident engineers shall preserve press copies of all official written communications sent out by them, in bound volumes, to be properly titled and indexed, and handed into the central office on completion of the work. They shall indorse and preserve all like communications received to the same end.

19. Principal assistant and division engineers will be supplied with copies of the contracts and specifications relating to their charges. They may be commissioned by authority of the chief engineer to negotiate contracts for labor, material or right of way in special cases, but all such contracts must be conditioned on the approval of the chief engineer, signed by himself or other immediate representatives of the company, and the orignals filed in the central office.

20. All subordinates of this department responsible for the right conduct of work, shall hold the contractors to its timely and proper execution, in accordance with the terms of the agreement and the requirements of the specification. They should not only be vigilant to prevent any hindrance to the contractors, but active and prompt to keep well in advance of them, so that there shall be no just cause of complaint for lack of stakes or instructions. All official communications to the contractors should be clear and explicit, and respectful in tone, and should be recorded at the time, as herein elsewhere directed. Orders and instructions shall be given in writing, when asked for by any contractor, sub-contractor or foreman.

21. Should it appear, in any case, that the conditions of a contract are likely to fail of fulfillment as to time of completion or otherwise, the associate engineer shall be seasonably informed of it, with a statement of the causes. Any radical remedies provided for in the contract must be administered by the chief engineer only, or by express authority from him.

22. All maps, drawings, papers and books should be clearly marked with titles, numbers and characters, and orderly bestowed and catalogued for ready reference in the offices of this department. Division engineers should see that their subordinates conform to this rule, and they should at frequent intervals inspect the instruments furnished their subdivisions, to make sure that they are kept in adjustment and not ill-used.

23. No original records shall be permitted to leave the respective offices, excepting as herein prescribed. Other departments or agencies of the company entitled to information from this department must be served by copy only, and not by the original drawings, sections or records, unless the chief engineer expressly warrants a deviation from the rule.

24. All regulations herein contained for the government of line engineers proper shall govern principal assistants and others in the special service of the department, to whom they are cleary applicable.

VII. INSPECTORS AND TIME KEEPERS.

1. Division engineers will be authorized, when it appears proper to the chief engineer, to employ inspectors for important structures. Such inspectors shall receive orders from and report directly to the resident en-

gineer. Division engineers will instruct their residents as to the duties of inspectors.

2. Each division engineer may, by like authority, employ a general time keeper, whose duty it shall be to keep a correct record of the labor and machinery employed on the work, properly classified and located, the wages paid, materials expended, and other notes concerning the progress of the work and the contractor's outlay.

3. The time keeper shall act under the immediate orders of the division engineer. Resident engineers and their subordinates should be instructed to co-operate with him, and he shall have power to employ additional help, subject to the approval of the division engineer, in the event of their assistance proving inadequate.

4. He should report weekly to the division engineer, and hand in a monthly statement of the force account of each subdivision, properly distributed, for reference by the division engineer of the residents.

5. Resident engineers and their subordinates should be so constantly on the line as to obtain an independent force account, approximately correct, for themselves. This they shall do, for comparison with that furnished by the division engineer, should a general time keeper be employed ; and, in case of any unaccountable discrepancy, call his attention to it.

6. Division engineers shall make monthly returns of force accounts, with their monthly estimates to the associate engineer, after a form provided by the central office.

7. Division engineers shall keep a book of force accounts, showing the items properly classified and distributed, and will compare and harmonize notes with the Residents when making up the Road Section Records herein prescribed (VI. 12).

VIII. ESTIMATES.

1. On or about the 27th of each month, resident engineers shall take measurements and make an estimate of the work done on each section of their respective subdivisions during the month current, statements of which estimates they shall prepare in duplicate on prescribed forms, one copy to be retained, the other to be delivered to the division engineer not later than the first day of the month following that to which they refer.

2. Division engineers shall prepare like estimates of the work done on each section of their respective divisions in quadruplicate and send three copies, duly authenticated, to the associate engineer, not later than the fifth day of the month following that to which they refer, accompanied by a force account, a recapitulation of work after such forms as may be provided, and abstracts for the progress profile herein before described (VI., 9). One copy of the estimate sheets and accompanying papers, excepting progress data, will be retained on his office file.

3. Quantities greater than those due to the net measure, as defined by the slope staking, the masonry plans or prescribed tunnel sections shall not be allowed in either the monthly or the final estimates; provided, however, that any extra expense incurred shall be clearly the result of slovenly conduct or violation of orders. If unsuitably slope-staked, if drawings are erroneous, or if slips occur in cuts and falls in tunnels from causes not reasonably to have been forecast and prevented, the extra work done may be covered by estimate, under instructions from the chief engineer.

4. In classifying estimates, the quality of masonry and the character of material removed, as described in the specifications, shall be regarded exclusively of all other considerations. If any case of losing merit occurs, employés in this department must bear in mind that such case is for the judgment and the action solely of those who pay the money, the engineer's duty being rigorous adherence to the requirements of the contract and specifications.

5. No employés of this department shall be interested in any contract, or in the furnishing of contractors' supplies on the line of the road, or in any business connected therewith, excepting that of the Company.

IX. ACCOUNTS, SUPPLIES AND SUNDRIES.

1. The pay-rolls and expense accounts for each month shall be prepared by the division engineers and transmitted, with their endorsements, on or before the fifth day of the month following, to the associate engineer.

2. After approval in the central office, checks will be sent to the division engineers for each individual to whom payment appears to be due, and the receipted pay rolls and expense vouchers shall then be returned to the associate engineer.

3. Division engineers shall book the salary and expense accounts of their respective divisions in the usual form, and shall report all discharges, appointments and transfers to the associate engineer at the time of such transactions.

4. The fixed salaries of the employés of this department shall be in full for all service and personal expense, excepting necessary outlays on the Company's business, for transportation and subsistence, by division engineers or their draughtsmen when called away from the Division Headquarters, and by resident engineers or their subordinates when called away from their Subdivisions.

5. Division engineers shall make formal requisition on the associate engineer for necessary equipment and supplies. They shall keep a record of all company property in their charge, and make report thereof quarterly, with inventory of articles on hand at date of previous report, received since, expended, in what manner or service, and on hand at date of current report, adding explanatory remarks.

6. Under the head of incidental expenses shall be included, and itemized, minor outlays for stationary and printing, office rent, fuel, lights and attendance, tools and repairs thereof, postage, telegraph and express charges, messengers on special errands requiring certainty and dispatch, and such small stores, needed in the progress of the work, as can best be obtained on the ground. In these matters, and in the conduct of their charges generally, division engineers are expected to practice a watchful and rational economy and to exact it of their sub rdinates, Incorrect estimates, slovenly records, laziness, drunkenness, erroneous field work, bungling use of instruments to their injury, squandering of road supplies for private account and the like should be followed by quick riddance of the culprit.

7. Offices should not be lounging places, and great care must be taken that no unauthorized persons have access to books, papers, or other information relating to the work.

8. No person appointed to or discharged from the company's service in this Department, shall be allowed expenses to or from the field of service.

X. MISCELLANEOUS INSTRUCTIONS AND SUGGESTIONS.

1. In slope staking, when material is doubtful, stake for rock. In such cases where earth cuts are started vertical, have a force to follow closely with trimmed slopes, to avoid irregular breaks and slips. Set side stakes

every fifty feet for trimmers. After stripping rock restake for it. Leave a berm of four feet between foot of earth slope and crest of rock in mixed cuts.

2. All curves should be slope-staked at intervals of fifty feet.

3. Where cut is in excess, have it wasted regularly along the convexed side of curve in adjacent fill, unless the possibility of flattening the curve in future makes it expedient to waste on the concave side. Waste symmetrically on tangents; if single track, on double track side,—subject to the condition that no overhaul shall be required and no increase of masonry, except by warrant from the central office.

4. Where fill is in excess on single track, first double track the adjacent cuts for a supply, if earth, and within overhaul limit. Should more material be needed, widen earth cuts to their utmost, leaving in every case room for berm ditch and additional four feet for fence berm.

5. Waste no material above grade unless imperative and authorized by the division engineer. Where material is permitted thus to be wasted, leave in every case a berm of not less than ten feet, and additional allowance for future extra track.

6. Be vigilant to prevent tresspass on adjacent properties in making side ditches, spoil banks, or otherwise.

7. Side and berm ditches should be opened in advance of graduation and kept open. Material from berm ditches should be ridged up regularly on down hill side; that from side ditches deposited in embankment. See that the outfall from ditches in cuts is turned aside so as not to scour the fills.

8. Where stream channels are changed the new channel should be side sloped, and a berm of twelve feet, with allowance for future extra track, left between its crest and foot of embankment.

9. On bare slopes, to be embanked, plow the ground lengthwise before filling in, and on very steep hillsides excavate terrace benches to hold the embankment.

10. Examine embankment sites for springs and have them carefully drained clear of the formation, by ditches filled with broken stone or cobbles.

11. Finish all earth or mixed embankments, full width at top and four per centum of the record center height above grade for the reception of ballast; rock embankments, two per centum. This is tentative, and subject to modification. It is believed to be sufficient allowance for embank-

ments made in layers or with scraper, and approximately correct for heavy dumped work on good bottom, which, advancing more slowly, must needs have gotten to its bearing in some measure before completion. Division engineers are invited to give their past experience on this point, and also to profit by their present opportunity for more knowledge concerning it.

12. In rock cuts see that no large masses, dislodged by blasting, are allowed to remain on the slopes or overhanging them. Examine all such masses with bars, and, where liable to be washed or frosted down, have them removed and duly entered in the estimates.

13. Require rock cuts and tunnels to be taken out full width and depth at once, and suffer no bottoming to be left over except by special permission of the chief engineer, in tunnels only, for the purpose of drainage during construction.

14. See that the road is graded true to line, and as staked out; that material needed elsewhere is not wasted at mouths of cuts; that side slopes in excavations are plane surfaces, not convex; that embankments are carried out the full width due to the slope staking at whatever level built; that their slopes are plane surfaces, not concave; that they are built in layers back of all abutment and culvert walls; that the centres of arch culverts are allowed generally to remain until the embankment has been carried by them; and, if removed, that the embankment is built in layers a proper height above crown of arch.

15. Approaches to crossings, in excavation or embankment, should be graded not less than twelve feet wide on top, and up to the height of top of rail—say two feet above the grade of formation; they should ramp or slope at a rate not exceeding one in ten, and be level a sufficient distance each side of the railroad to prevent the possibility of stone or timber trucks stalling on the track.

16. Meeting grades should be rounded off with vertical curves at least six hundred feet long; and as much longer, especially in the case of pockets, or cylindrical grades, as economical conditions will permit. Special instructions will be given on this subject.

17. Be cautious not to allow full measure in monthly estimates before the work is settled, surfaced and trimmed; a safe reserve should be held usually for such items.

18. In retracing line during construction, or after graduation, use the original turning points established on the final revision of the line.

19. Timber and brush should be cleared the full width of right-of-way, and valuable timber piled up along the right-of-way, and saved for the company, where the clearing is done by the contractor. Trees on abutting properties whose accidental fall might encumber the track, should be legally condemned and felled.

20. Avoid small openings in the roadbed, using box or arch culverts preferably.

21. The road-bed should be trimmed to a crown of three inches above grade in the middle, to promote lateral drainage under the ballast.

22. Sound doubtful foundation pits with an iron rod, and make sure of a good bottom. Drain them when feasible. Where not liable to wash or to subsequent exposure, two feet of gravel, shingle or broken stone, well rammed, makes an excellent foundation course.

23. See particularly to the deep and safe founding of walls and curbs at the outfall end of drainage structures.

24. Before sizing opens for culverts and bridges search the water down stream for some point where flood volume is well marked, and work by that.

25. Observe and report streams suitable for water supply.

26. Insist on specification requirements in masonry. Make it clearly understood that no excess of neat work beyond scale plans will be estimated. No crushable chips. No grouting unless specially authorized. Flush up solid instead, with mortar as stiff as it will work readily. Good bond imperative, and to take precedence of outside looks.

27. Clear away the surplus stone and wreckage from masonry sites after the jobs are done; and before the completion of each section, have blasted rock and all other cumber accumulated during construction removed from adjacent properties and highways.

28. In establishing outside tunnel lines by daylight, the best time has been found to be just after sunrise, and the best sight pole a half-inch round iron rod painted white. Plummet lamps, on clear calm nights, have given better results than sight poles by day, being distinctly visible at long distances.

29. To transfer line down a shaft, set transit point at a distance therefrom of about twenty-five feet, from which point, with a long foresight two staples or other guides, may be ranged on the side timbers overhanging the pit, and the centre line thence plumbed to the bottom with fine

copper wires, bobbed as heavily as they can bear, the bobs immersed in water. It has been necessary in some cases to box in the wires, to protect them against water and air currents. Careful manipulation, patient and repeated observations, and a discreet average of them are required for a correct transfer.

30. The range at bottom must be transferred to wooden roof plugs, in which eyescrews, staples or other suitable fixtures are ranged, and from which plummet lamps may be hung when required.

31. Bench marks are established similarly in the roof, being stubs of steel fastened into holes or chinks, the elevations of which are obtained by means of a reversed rod. The levels may be transferred from the surface with a steel tape or wooden rods.

32. All centre points and bench marks should be placed out of danger from rocks thrown by blasting.

33. Standard measures should be made at the outset by which to test, from time to time, the tapes, level rods and other field measures used on the work, as it is important that these measures be uniform, and guarded against change.

34. For leveling underground a target with a diamond-shaped opening in it has been found convenient, one of the diagonals of said opening being horizontal. The rod is plumbed with a portable level bubble made for the purpose, and a light is held behind the target at the time of observation.

35. Division engineers will supplement these general memoranda as to tunnel surveying, and will find room for their ingenuity in expanding and diversifying them to suit various practice.

36. Require tie-contractors to pile the ties regularly, both ends visible, and spaced suitably for inspection, within not less than fifteen feet nor more than forty feet from the centre line of double-track road bed, and not over two feet below grade, when the nature of the ground will admit of compliance with this rule. When it will not, then require them to be delivered and piled where they can be conveniently got at by the tracklayers.

37. After tracklaying, and before opening the road to traffic, a flat car should be run its whole length each way, with templates, fixable crosswise, for testing the clear width of rock cuts and dimensions of tunnel sections. Every point encroaching on the standard section should be

marked with red paint from a large "whitewash" brush, and removed promptly by a floating gang.

38. The terms "grade line" and "grade," as herein used, refer to the surface of the road bed, at the established profile grade; that is to say, to the bottoms of cuts and the tops of fills, as prepared for the reception of any crowning to promote lateral drainage and of the railway proper, or superstructure, comprising ballast, ties and rails. The term subgrade is omitted as superfluous and confusing, and is not to be used on this road. The elevations of bridge seats, bridge structures and their parts. foundations, piers, trestle-work, rails, cross-ties, and all other details requiring such reference shall be referred to the elevation of "grade," by plus and minus signs.

39. Some of the rules contained in this article are intended to be suggestive rather than mandatory—practical hints and instructions. Division engineers and all others concerned are invited to report any discrepancies, errors or deficiencies, which they may observe, either here or elsewhere, in the present compilation, and to suggest what they judge to be improvements, corrections or useful additions. Regard any rules as invalid which may appear to conflict with provisions in the contract and specifications, or to call for expense not therein contemplated.

WM. F. SHUNK,
Associate Engineer.

APPROVED:

ROBT. H. SAYRE,
Chief Engineer.

INSTRUCTIONS TO DIVISION AND ASSISTANT ENGINEERS RELATIVE TO FIELD NOTES ON SURVEYS FOR THE SOUTH PENNA. R. R. CO.

First—Enter the names of the Division Engineer, Senior Assistant Engineer in charge of the party, Assistant Engineer at Transit Instrument, Assistant Engineer at Leveling Instrument, Rodmen, Chainmen, Flagman, Axemen, composing the party. Rodmen must make the same notes, also enter the date and place where the work is.

Second—State in the column of remarks on the first or second page of the book at the beginning of the notes of any survey or levels, the letter of the line and where it was begun and where it is to be run to.

Third—The Stakes of all lines must be numbered on the rear face, next to the transit, and must be lettered on the forward face, with the letter of the line. All lines must be lettered.

Fourth—State what Datum the Levels start from or refer to, and if started from a Bench state what Bench and from what authority or book the Elevation was obtained.

Fifth—Enter all notes of Transit or Level fully and distinctly in pencil in the field—if any details or calculations are omitted from haste or sudden storms coming up—make them complete before the day is over, and when required by the Senior Assistant or Division Engineer, they must be recorded in a Record Book the same evening.

Sixth—All field notes must be compared during the day taken, and all Levelers' calculations on turning points must be made by Assistant and Rodman, and compared on the spot and found correct before going forward with the work.

Seventh—Benches must be made at least once in every mile, and oftener if opportunity offers. Levels must be tested on any existing Benches found along the line, and tests made of the accuracy of the old and new works. Benches must not be cut on shade or fruit trees and no unnecessary damage done in clearing the line of sight; offsets must be made to save valuable trees

Eighth—In passing through inclosed land the Senior Assistant will see that the fences taken down by the party are put up after they pass forward.

Ninth—The Assistant at the Transit must record the names of land owners, the points where boundaries are crossed, and their courses when obtainable.

Tenth—Chiefs of Party must arrange to get the party out and at their work as early as possible in the morning, and keep them employed until the proper hour in the evening. All preparations for the field work must be made by the Senior Assistant and Assistants the previous evening, so that no delays may occur in the morning. Dinner will be procured by the Senior Assistant to be eaten in the field when the party is more than one mile from boarding places.

Boarding expenses paid by any members of the party will be reported to the Senior Assistant and will be repaid by the company at the end of the month.

Eleventh—Senior Assistants will see that the instruments, rods and chains are kept in good order and adjustment by the Assistants; any damage to instruments or rods from want of proper care must be defrayed by the Assistant having the same in charge.

Twelfth—Daily notes of the work done and the date must be entered in this field book every evening.

Thirteenth—Assistant Engineers in charge of the Transit must plot their lines, and Assistants in charge of the Level must, with the aid of their Rodman, make a profile every evening, of the line leveled over each day.

Fourteenth—Division and Senior Assistant Engineers will make reports of instruments and stationary on hand at the close of each month, and send them in promptly to the General Office.

Fifteenth—Division Engineers must report any neglect of these instructions to the Chief Assistant Engineer.

OLIVER W. BARNES, Chief Engineer.

CHAPTER IV.

Topography, and Staking-out Problems.

TABLE FOR COMPUTING RIGHT OF WAY AREAS.

Width 100 ft.

Stations.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9		
												Feet.
0...	0.000	0.023	0.046	0.069	0.092	0.115	0.138	0.161	0.184	0.207		
1...	0.230	0.253	0.276	0.299	0.322	0.345	0.368	0.391	0.414	0.437	.01	.0023
2..	0.460	0.483	0.506	0.529	0.552	0.575	0.598	0.621	0.644	0.667	.02	.0046
3...	0.690	0.713	0.736	0.759	0 782	0.805	0.828	0.851	0.874	0.897	.03	.0069
4...	0.920	0.943	0 966	0.989	1 012	1.035	1.058	1.081	1.104	1.127	.04	.0092
5 ..	1.150	1.173	1.196	1.219	1.242	1 265	1.288	1.311	1.334	1.357	.05	.0115
6...	1.380	1 403	1.426	1.449	1.472	1.495	1.518	1.541	1.564	1.587	.06	.0138
7...	1.610	1.633	1.656	1.679	1.702	1.725	1.748	1.771	1.794	1.817	.07	.0161
8...	1.840	1.863	1.886	1.909	1.932	1.955	1.978	2.001	2.034	2.047	.08	.0184
9..	2.070	2.093	2.116	2.139	2.162	2.185	2.208	2 231	2.254	2.277	.09	.0207
10...	2.300	2.323	2.346	2.369	2.392	2.415	2.438	2.461	2.484	2.507	.10	.0230
11...	2.530	2.553	2.576	2.599	2.622	2.645	2.668	2.691	2.714	2.737	....	.....
12.	2.760	2.783	2.806	2.829	2.852	2.875	2.898	2.921	2.944	2.967		.....
13...	2.990	3.013	3.036	3.059	3.082	3.105	3 128	3.151	3.174	3.197	....	.....
14...	3.220	3.243	3.266	3.289	3.312	3.335	3.358	3.381	3.404	3.427	....	.....
15...	3.450	3.473	3.496	3 519	3.542	3.565	3.588	3.611	3.634	3.657	....	.....
16.	3.680	3.703	3.726	3.749	3.772	3.795	3 818	3.811	3.864	3.887	....	.....
17 ..	3.910	3.933	3.956	3.979	4.002	4.025	4.048	4.071	4.094	4.117	....	.....
18...	4.140	4.163	4.186	4.209	4.232	4.255	4.278	4.301	4.334	4.347	....	.....
19...	4.370	4 393	4.416	4.439	4.462	4.485	4.508	4.531	4.554	4.577	....	.....
20. .	4.600	4.623	4.646	4.669	4.692	4.715	4.738	4.761	4.784	4.807	....	.....
21...	4.830	4.853	4.876	4.899	4.922	4.945	4.968	4.991	5.014	5.037	....	.....
22...	5.060	5.083	5.106	5.129	5.152	5.175	5.198	5.221	5.244	5.267	....	.....
23...	5.290	5.313	5.336	5.359	5.382	5.405	5.428	5.451	5.474	5.497	....	.....
24...	5.520	5.543	5.566	5.589	5.612	5.635	5.658	5.681	5.704	5.727	....	.....
25...	5.750	5.773	5.796	5.819	5.842	5 865	5.888	5.911	5.934	5 957	....	.....
26...	5 980	6.003	6.026	6.049	6.072	6.095	6.118	6.141	6.164	6.187	....	.. ...
27...	6.210	6 233	6.256	6.279	6.302	6.325	6.348	6.371	6.394	6.417	....	.....
28...	6.440	6.463	6.486	6.509	6.532	6.555	6.578	6.601	6.624	6.647	....	.....
29. .	6 670	6.693	6.716	6.739	6.762	6.785	6.808	6.831	6.854	6.877	....	.....
30...	6.900	6.923	6 946	6.969	6.992	7.015	7.038	7.061	7.084	7.107	....	.....

Having the distance between the boundaries of the tract through which the line passes, find the number of stations in the left hand column and in the column of tenths under .0 to 0.9 will be found the acres required, if the plus is an even 10 ft. If the plus contains odd feet the correction to be added is found in the column of feet.

TOPOGRAPHICAL FIELD WORK.

The topographical party consists of three persons: a chief, often called the topographer, and two assistants, called the levelman and the rodman. The field work is generally one day behind that of the transit and level parties in order that their notes may be utilized.

The topographer is provided with a drawing board about 16 by 18 inches, having raised edges, thus forming a kind of box 14 by 16 inches, in which is kept several sheets of paper ruled into squares, two triangles, a scale, protractor and pencils, the whole being covered by a leather flap when not in use. He also carries a small compass.

The levelman carries a Locke level, which can be mounted upon a rod about five feet long, so that when set it is exactly five feet above the surface of the ground. This rod should be graduated in feet and tenths from the foot upward, and it is sometimes convenient to have it rectangular in section, so that it can be used as a slope board. He also carries a clinometer, and a note book having the right-hand page ruled into squares.

The rodman carries a tape line, and a rod either 10 or 15 ft. in length, plainly graduated in feet and tenths, the zero being at the foot. He will often find it convenient to carry a hatchet.

METHOD OF LOCATING CONTOURS.

The object of the topographical work is to obtain the data for plotting the contours on both sides of the line, and also the streams, roads, houses, and other natural and artificial features. The general custom is to take contours at every five feet of vertical height.

When the transit and level parties have finished a day's work, the topographer takes their field books and plots the line upon his sheets, recording the intersection angles, the bearings, the elevations of the stations and of the streams and roads crossed by the line. His levelman also records the same elevations in the field book, arranging the notes so as to read upward from the bottom of the page.

The next morning the topographical party starts where the transit and level notes began. The levelman sets his Locke level at the first station, which we will suppose to be No. 25, whose elevation is 372.6 feet. The height of the instrument is then 377.6 feet. The rodman moves down the slope at right angles to the line, and is directed to stop by the levelman when his line of sight cuts the rod at 7.6 feet. The foot of the rod is then on the 370 foot contour, and its horizontal distance from the station is measured and recorded. The rodman then moves down until the level-

man reads 12.6 feet on the rod, when its foot is on the 365 contour. The levelman must now move to this last point, set up his level, and the rodman goes down the slope until his rod reads 10.0 and 15.0 feet, which give the 360 and 355 contours respectively. The process is thus continued as far as desired, the distance to each contour being recorded always from the station for convenience in subsequent plotting and computations.

In going up the slope on the other side of the line the rod should be placed at station 25, and the 380 and 385 feet contour planes then cut the rod at the readings 7.4 and 12.4 feet respectively. The levelman goes up the slope at right angles to the line and sets his level, so that the line of sight reads 12.4, when he is on the 380 feet contour, and the height of the instrument is 385 feet. The rod is now brought forward, and the other contours located and recorded, and the process is continued as far up the slope as desired.

After taking the contours for a certain distance on each side of the line at a station some topographers make a note of the general slope of the ground for some distance farther, measuring the inclination by the clinometer and slope board.

FIELD NOTES.

Notes of the position of each contour at each station are kept by the levelman on the left hand page of his field book, the manner of arrangement being as here shown:

200	46	22	.15	375.5	2	27	8.6	300	
50	390	385	380	26	375	380	385	4°	
200	89	49	7	372.6	13	40	79	104	250
6°	385	380	375	25	370	365	360	355	5°

In the middle column are placed the numbers of the stations and their elevations as obtained from the notes of the level party. In the right column are given the distances from the station to each contour on the right of the line, it being 13 feet from station 25 to the 370 contour, 40 feet to the 365 contour, and so on. The last entry shows that the ground has the uniform slope of 5 degrees from the 355 contour to a distance of 250 feet from the station. In like manner the notes of the contours on the left hand side of the line are placed in the left column.

FIELD PLOTTING.

While the levelman and rodman are taking these notes the topographer plots on his sheet the point where each contour is located at the right and left of station 25. Also by the help of a table pasted on his drawing-board he marks the points where the contours fall on the uniform slopes at the sides. This table is the following, giving the horizontal distance in feet between two five foot contours for different slopes of the surface of the ground.

Slope of surface.....	1°	2°	3°	4°	5°	6°
Distance between contours, feet...	286	143	95	72	57	48

It is easy to prepare a more extended table, since the distance is five times the natural co-tangent of the slope.

The party then moves to station 26 where the same operations are repeated, and the topographer, orienting his drawing board (that is, placing the plotted line parallel to the line as run) is able to connect the corresponding contour points at station 25 with those at station 26. With a little experience this can be done in the field to a far greater precision than by any office work. If the ground is irregular between stations intermediate work may be necessary, but with the ground in front of his drawing board the skilled topographer will rarely need such data except when necessary to be noted for the purpose of earthwork estimates.

The record kept by the levelman in the field book furnishes the means of plotting the contours in the office in case a sheet of topography should be lost, and it will also be needed in making estimates of earthwork which are often needed in deciding upon the final position of the line.

On the right-hand page of the field book the levelman or the topographer will keep the record of all the distances measured to streets, buildings, fences or other objects, together with a sketch of their location. Some of these, particularly streams, edges of marshes, roads and winding fences, he may also prefer to plot upon his sheets in the field instead of waiting to do it in the office. But well-defined objects, such as houses and straight fences, may be as well deferred to office hours if the topographer is pressed for time in the field. The instructions given to a topographer by his chief or locating engineer will decide in regard to these details.

LOCATING BUILDINGS.

In locating buildings young topographers generally attempt to measure offsets from the corners at right angles to the line. This is only advisable where the sides of the building are closely parallel and perpendicular

to the line. If a building stands obliquely to the line it will be best to measure the offsets obliquely also so as to be in line with two of the sides, but the bearings of the oblique offsets should be noted or the angles which they make with the line. On preliminary work fences can be determined by compass bearings and some little pacing, and in all kinds of work it is desirable that the levelman and rodman, as well as the topographer, have the ability to determine pretty accurately the length of a line by pacing.

METHODS OF SETTING SLOPE STAKES.

I.

When the ground at a station is level the slope stakes are easily set by the use of the tape alone.

Let B = width of road bed.

Let C = center cut or fill.

Let s = side slope, usually $1\frac{1}{2}$ to 1.

Then the distance from the station to each slope stake is

$$H = \tfrac{1}{2} B + s C.$$

For example, if the roadbed is 18 feet wide and the side slope $1\frac{1}{2}$ to 1, the distance out is

$$H = 9 + 1\tfrac{1}{2} C.$$

If $C = 6.2$ feet, the distance H is 18.3 feet, and this is to be laid off with a taper on each side of the station.

II.

When the ground at a station is not level it is usually the custom to find the position of the slope stake by successive trials. The following is the method as generally carried out in the field:

The leveler, having obtained the amount of fill required at the station, which we will assume for convenience to be 3 feet, judges, after closely observing the ground, that the fill or distance of the ground below grade at the point of intersection of the slope with the natural surface which he is seeking, is about 9 feet greater than at the center, or 12 feet in all. If this supposition be correct, the point required will be at a distance out equal to one and a half times the assumed fill plus half the roadbed at grade; that is, if the altitude $E E'$ of the triangle $B E E'$ is equal to 12, then its base $B E'$ will equal 18 (the slope being such that each foot of altitude or fill requires one and a half feet of base), and the total distance out $C' E'$, will be the base $B E'$ plus half the roadbed (assumed as 9 feet), or $18 + 9 = 27$. The rodman now holds his rod at this distance

out, and the rod reading subtracted from the *H. I.* gives the elevation of the ground at the point, and this elevation subtracted from the elevation of grade gives the fill or distance of the point below grade. But the fill at 27 feet out, instead of being 12 feet as was assumed, proves to be but 10 feet, showing that a point twelve feet below grade is below the natural surface, and therefore beyond its point of intersection with required slope. Since, therefore, any assumption greater than 12 feet would only carry us further from the desired point, let us assume for a new trial a smaller number, say 6 feet, with corresponding distance out of $6 + \frac{6}{2} + 9 = 18$ feet. But the rod having been held at this new distance out, we find the depth of the point below grade to be 7.6 feet, instead of 6 feet as was assumed, and holding the rod anew at the distance out correspond-

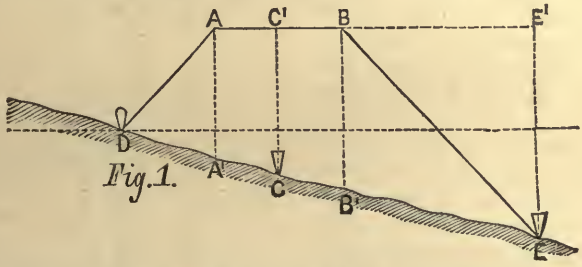


Fig. 1.

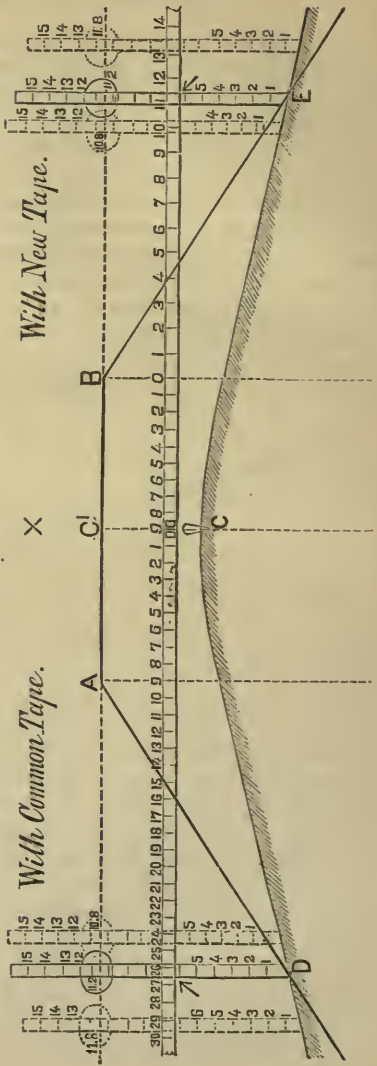
ing to a fill of 7.6 feet—that is, $7.6 + \frac{7.6}{2} + 9 = 20.4$ feet—we find the depth of this new point to be 8.4 feet below grade, which requires a still greater distance out—that is, $8.4 + \frac{8.4}{2} + 9 = 21.6$ feet. But it will be observed that with each new trial the difference between the assumed and calculated distances is decreasing, and that therefore we are gradually approaching the intersection, and are very near it, as the difference between the two last distances was very small. Adding now but a small quantity, say 0.6 foot, to our last trial fill, which was 8.4 feet, we have 9 feet, and taking a rod reading at the corresponding distance out, 9. $+ \frac{9}{2} + 9 = 22.5$ feet, we find the actual distance of the ground below grade to be 9 feet, and that the measured distance out agrees with the calculated distance, proving the last assumption to have been correct, and the stake is now driven at the point thus found. The number of trials or approximations necessary to determine this point varies with the regularity of the rise or fall of the original surface, and with the experience of the leveler.

The application of this method to a case in excavation scarcely needs a separate explanation, the same prism being merely inverted, and the

level being always above grade, instead of sometimes above and sometimes below as in embankment.

III.

When a large amount of work is to be done in side slopes of $1\frac{1}{2}$ to 1 it is sometimes advantageous to have a tape graduated with distances of one and a half feet marked as feet over a part of its length. The cut shows the method both with the common tape and with the new tape. This cut, with the following description of its use, is taken from a small pamphlet published by Keuffel & Esser, New York.



Let us assume, as was done in the explanation of the common method, that in descending toward the point at which the slope stake is to be set, the ground has fallen 9 ft., or is in all 12 ft. below grade, that is, we assume that the distance $E\,E'$, or its equivalent $B\,B''$, is 12 ft.; if this is correct, the point E must be, in order to satisfy the conditions of the slope, at a distance from B'' equal to 12 of the divisions of our new tape (see Fig. 5), or, since the tape-ring is held at the center stake C, E must be 18 ft. further out than the point B, the O on our new tape; which being nine feet from the ring, had already carried us out to B''. But the rodman having held his rod at the assumed point, that is, at division 12 of the tape, the leveler

tells him that the fill, instead of being 12 ft. at that point, as was supposed, is but 10 ft., the rodman, therefore, knowing that the number given him by the leveler indicating the amount of fill, must be identical with the number on the tape indicating distance out, that is, that the number of the divisions of the vertical line must be the same as the number of divisions of the horizontal line, sees at once that he is not at the right point, but that he is too far out, as the number of divisions on the tape is greater than the number of divisions in the height of fill, so he holds at a new point further in, say at six. The leveler having taken a rod-reading at the new point, tells the rodman that the fill there is 7.6 ft., and the rodman sees at a glance that he is not at the right point, since the horizontal number six of the tape does not agree with the vertical number 7.6 given him by the leveler, and he knows that he is too far in, and therefore tries the rod at a point further out, say at division 9. The leveler having read the rod at the new point, sings out "fill nine feet," which, being the same as the tape reading, the rodman knows he has found the right point, and drives the stake. It will be observed that the only calculation the leveler has had to make for each of these trials has been simply that necessary to find the distance below grade of each trial point, the rodman having found his own distance out by merely glancing at his tape, prepared for that purpose. If it is desired to record in the note-book the actual distance out from the center stake it is only necessary to turn the tape over and read off the entire length of the line C'' E in feet and tenths as usual.

IV.

When the surface of the ground at a station has a uniform slope transversely, some engineers prefer to calculate the distances out of the slope stakes by formulas.

Let B=width of roadbed.

Let C=center cut or fill.

Let S=tangent of inclination of side slope.

Let T=tangent of inclination of cross slope of ground.

Then the distance out to the up hill slope stake in cut, or to the down hill slope stake in full, is

$$H_1=\frac{C+\frac{1}{2}\,S\,B}{S-T},$$

and the distance out to the down hill slope stake in cut, or to the up hill slope stake in fill, is

$$H_2=\frac{C+\frac{1}{2}\,S\,B}{S+T}.$$

The quantity $\frac{1}{2}SB$ is a constant quantity for each given roadbed and side slope. For example, if the width of roadbed is 18 feet, and the side slope is $1\frac{1}{2}$ to 1, then $\frac{1}{2}B=9$ and $S=\frac{2}{3}$, whence $\frac{1}{2}SB=6$ and the formulas become

$$H_1=\frac{C+6}{\frac{2}{3}-T}$$

and

$$H_2=\frac{C+6}{\frac{2}{3}+T}.$$

The values of T may be measured directly in the field by having a rod exactly ten feet long held exactly level with one end on the ground; then the vertical distance from the other end to the ground is ten times T; or if the slope be observed by the clinometer in degrees, the values of T can be taken from a table of natural tangents. For example, if the uniform cross slope is $4\frac{1}{2}$ degrees, the value of T is 0.0787. Then if C is 6.2 feet, the distances out are

$$H_1=\frac{6.2+6}{0.6667-0.0787}=20.7 \text{ feet.}$$

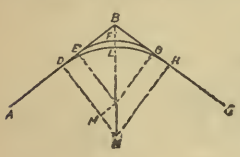
and

$$H_2=\frac{6.2+6}{0.6667+0.0787}=16.2 \text{ feet.}$$

If the surface changes its slope between the slope stakes, these formulas will not apply except approximately. In such cases the method of trial can alone be relied upon to give satisfactory results.

FLATTENING A CURVE.

Having located the curve $E\,F\,G$, joining the tangents $A\,B$ and $B\,C$, it is desired to join the tangents by another curve which shall pass through the point L, distant a from F.



Let radius $E\,I=r$, radius $D\,K=R$, $F\,L=a$. Angle at center $=2\,\theta$. Draw $M\,I$ parallel with $A\,B$.

In the triangle $I\,M\,K$ we have angle $K=\theta$, angle $M=90°$. Side $I\,K=R+a-r$, side $M\,K=R-r$ then

$$R+a-r=\frac{R-r}{\cos\theta}.$$

Transposing and reducing, $R=\dfrac{r+\cos\theta\,(a-r)}{1-\cos\theta}$.

$M\,I=D\,E$ distance to move back on tangent in flattening curve $=(R-r)\tan\theta$.

A. B. & O. ENGINEER.

STAKING OUT SWITCHES.

BY J. F. LE BARON, C. E.

The first thing is to find the radius R of the center line of the turnout curve. To find this we must have the following data:

The gauge of the track $= g$.

The "throw" of the switch rail $= d$, which is generally taken as 5 inches.

The angle which the switch rail makes with the main track $= S$, which varies, of course, with the length of the rail. The length varies from 18 to 30 ft.

The frog angle $= F$.

The radius R of the center line of the turnout is then found by Henck's formula, adapted to logarithms:

$$R + \tfrac{1}{2}g = \frac{\tfrac{1}{2}(g - d)}{sin.\ \tfrac{1}{2}(F + S)\ sin.\ \tfrac{1}{2}(F - S)}.$$

From this we have R by subtracting the value of $\tfrac{1}{2}g$.

We now proceed to compute the position of the point of the frog, which is located in reference to the throw or mouth end of the switch rail.

Referring to the figure, we will call the distance from the mouth of the switch to the point of the frog $B\ F$.

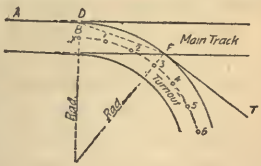
$$\text{Then } BF \text{ by Henck's formula} = \frac{g - d}{sin.\ \tfrac{1}{2}(F + S)}.$$

We are now ready to stake out the switch or turnout. Two cases may occur:

1st. The location of the switch throw may be fixed.

2d. The location of the frog in the track may be fixed.

In the first case the position of the switch throw being fixed, we will drive a hub with nail in the center (x) of the proposed turnout opposite the switch throw, determining its position by measuring from the rail one-half the gauge of the track plus the throw of the switch, which last we will consider to be 5 ins. Theoretically, this should be measured at right angles to the position of the switch rail in the turnout; but, practically, it can be measured at right angles to the rails of the main track. Mark a point (D) on the inside of the rail of the main track opposite this for the end of the switch rail, and measure back on the iron the length chosen for the switch rail, and mark a point (A) on the inside of the rail for the heel of the switch rail. The length of the switch rail is generally 20 or 22 ft., but this may be varied to



save cutting the iron. Short switch rails are more easily worked and are safer, but less than 18 ft. is objectionable, as not apt to make a smooth running curve and liable to jar the train. We now measure off the chord (BF), which we have previously found by computation from the throat of the switch, and .42 of a foot from the inside of the rail of the main track, swinging in the dist. (BF) to such a point (F) as it will touch the inside edge of the rail of the main track. This gives the position of the point of the frog in the track, which we mark on the rail.

The section master will set the frog in the track at this point without further marking.

We now set up the transit on the hub at x and lay off the curve of the turnout—the radius of which we have already computed—by setting stakes in the center line every 12½ ft., using a parallel to the switch rail in its position in the turnout, for tangent and deflecting as usual.

We know the radius of the turnout, and we can consequently compute the ordinate for bending the rails by the formula on page 14 of Henck, $m = \frac{\frac{1}{4}l^2}{2R}$, in which m equals the ordinate required in decimals of a foot, and l equals the length of the rail used. It can also be taken from Table I. (*ibid*).

The angle S which the switch rail makes with main track is easily computed, as we know or assume the length of the switch rail and the throw of the same, and therefore $sin.\ S = \frac{d}{l}$.

The frog angle F is known or easily found by measuring the frog, and computing, or by taking a paper pattern of the point angle and applying a protractor.

In the second case, where the point of the frog is fixed in the main track, we have to locate the switch throw from this point by measuring back the chord BF to a point B, 0.42 ft. from the main track rail.

In the case of a switch with a double throw, where two turnouts leave the main track from the same point, it is well to paint the stakes of each turnout a different color, to avoid confusing the trackmen.

We have supposed the main track to be on a straight line. If the turnout is from a curve the problem is more complicated, but it can easily be solved by prob. 57, page 38, Henck.

As a check upon the somewhat long computation required when the turnout is from the inside of a curve I have sometimes adopted the fol-

lowing mechanical method of obtaining the position of the point of the frog and the frog angle :

I set up the transit on the switch throw at *B* and lay out the outer rail of the turnout by deflection angles to any assumed radius, finding the point of the frog by repeated trials of deflection, and then measuring the frog angle by means of a light board with a nail driven through it at the point of the frog. This nail in the board is set over the point of the frog when found, and a pattern of the frog angle made on it by means of deflections with the transit, to establish the curve on the board. From this curve the tangent *T* at *F* is laid off and the frog angles measured with a protractor, or otherwise.

This method uses the rad. for the outer rail only, and saves computation for the frog angle and position.

The method I have described makes the turnout curves tangent to the switch rail, and consequently compounds the curve from *B* to *A*. This is no practical detriment, for generally the difference in radius is very slight, between the radius of the switch rail and the rest of the turnout, which is more than overcome by the manipulations of the trackmen.

Some engineers, however, prefer to make the curve tangent at the heel of the switch rail *A*. In that case the throw of the switch rail must sometimes be slightly changed (only a slight change is admissible with ordinary iron) or the length of the switch rail must be changed. But for safety in traffic the length of the switch rail should not be much increased, and if diminished nothing is gained.—*Engineering News*, Sept. 9, 1892.

METRIC RAILWAY CURVES.

[Fom Engineering News, Oct. 13, 1883.]

Several inquiries have appeared from time to time in ENGINEERING NEWS for a metric table of railway curves. We to-day present one prepared by an engineer who, after practicing the American method of laying out curves in the United States, has been for two years occupied in railroad surveying with the metric system in Mexico.

The table is explained by the headings of the columns. Curves are designated (as in the first column) by the angle which, according to the American system, has to be turned off repeatedly at a point on the circumference, and is subtended by successive equal chords. This angle is called by Trautwine and Shunk the "tangential" angle; by Henck and Searles the "deflection" angle. In the first article of the appendix to his revised edition, Prof. Henck suggests the use of this angle for designating curves run by the metric system. An obvious advantage thus gained is that the angle to be measured in staking out a curve in a field is simply the angle named in speaking of the curve. The equal chords successively measured according to the metric system should be 20 meters in length, as was abundantly enforced by numerous writers who discussed the point in ENGINEERING NEWS a year and a half ago. As to the adaptability of that length to railroad engineering, it may be noticed that in the first example of staking out a curve given in Shunk's "Field Engineer," the length of chord is taken to be 20.12 m., which he calls 66 feet. The stakes, set at successive 20-meter intervals, are to be marked with the successive *even* numbers, 2, 4, 6, 8, etc., so as to constitute the dekameter the unit of stake numbering. Each stake is thus designated by its distance in dekameters from the zero point, and each kilometer stake is marked by an exact hundred. The angle by which the curve changes its direction per unit of length as thus marked is, therefore, one-half of its change of direction between the extremities of the 20-meter chord; that is, it is exactly the "20-meter chord" angle used to stake it out and to designate it; and the total change of direction made by any length of the curve is simply the product of this angle multiplied by the difference

in the numbers of the stakes at its beginning and end, just as in the present practice in the United States.

For convenience in staking fractional parts of the 20-meter chain, the second column of the table is given, showing the number of minutes to be turned off with the transit per meter, being simply one-twentieth of the angle in the first column. Here a slight advantage over the 100-ft. chord is seen, because 60 bears a simpler relation to 20 than to 100.

The column of radii presents a simplicity superior to the 100-ft. system, in that the metric radius is just 10 times the co-secant of the angle in the first column, and can therefore be taken directly from a trigonometrical table by altering the decimal point, or in the case of the logarithm, the characteristic. The computation in the present United States practice is a little more complicated. The difference thereby produced in the figures may be seen by comparing the columns of 20-meter chord angle and radius with the columns of degree of curve and radius in the field-books commonly used in this country. The metric radii, instead of being figured exactly one-tenth of the expression in feet corresponding to the same angle, have slightly larger decimals. The discrepancy is so small, however, that for the greater part of railroad work the old tables might be used with the metric system, by taking the old degrees for the 20-meter chord angles and dividing all the old radii by 10, that is, merely changing the decimal point one place. It is different with the figures for deflection distances and ordinates, which, in the metric table, are almost exactly four-tenths of what they are in the old tables for the same angle in first column.

The precise length of the curve, in contradistinction to that of the chords by which it is staked out, is seldom required. The last column in the table is inserted chiefly with a view to exhibiting the percentage to be added to such a chord to get the length of arc it subtends. This percentage is clearly seen when we move the decimal point of the last column one place to the left; and it may be made useful in connection with such tables as are given at the end of Shunk's "Field Engineer" and of the revised edition of Henck's "Field Book." For example, those tables give, among other very useful data, the distance from the intersection point to either extremity of a one-degree curve whose total length varies between 0° and 90°. Mr. Shunk calls this the "apex distance;" Prof. Henck, the "tangent." For a curve 90° in length, Mr. Shunk's table gives 5730 ft. Prof. Henck's, 5729.7 ft., the same, of course, as the radius. Either of these divided by 10 can be used in practice for the metric 1° curve, whose

20 M. Chord Angle.	Minutes to be laid off per meter.	Radius in meters	Logarithm of radius.	Deflection. From tangent.	Deflection. From chord.	Ordinate at distance from end-chord. Middle. Of 10 m.	Ordinate at distance from end-chord. Quarter point. Of 5 m.	Length in meters of Arc of designated number of degrees.
0° 10′	0½′	3437.75	3.5362745	.058	.116	.015	.011	10.0000
20′	1′	1718.88	3.2352463	.116	.233	.029	.022	10.0001
30′	1½′	1145.93	3.0591581	.175	.349	.044	.033	10.0001
40′	2′	859.46	2.9342237	.233	.465	.058	.044	10.0002
50′	2½′	687.57	2.8373192	.291	.582	.073	.055	10.0004
1° 0′	3′	572.99	2.7581447	.349	.698	.087	.065	10.0005
10′	3½′	491.14	2.6912059	.407	.814	.102	.076	10.0007
20′	4′	429.76	2.6332231	.465	.931	.116	.087	10.0009
30′	4½′	382.02	2.5820810	.524	1.047	.131	.098	10.0011
40′	5′	343.82	2.5363351	.582	1.163	.145	.109	10.0014
50′	5½′	312.58	2.4949553	.640	1.280	.160	.120	10.0017
2° 0′	6′	286.54	2.4571808	.698	1.396	.175	.131	10.0020
10′	6½′	264.51	2.4224340	.756	1.512	.189	.142	10.0024
20′	7′	245.62	2.3902659	.814	1.629	.204	.153	10.0028
30′	7½′	229.26	2.3603204	.873	1.745	.218	.164	10.0032
40′	8′	214.94	2.3323107	.931	1.861	.233	.175	10.0036
50′	8½′	202.30	2.3060020	.989	1.977	.247	.186	10.0041
3° 0′	9′	191.07	2.2811998	1.047	2.093	.262	.196	10.0046
10′	9½′	181.03	2.2577414	1.105	2.210	.276	.207	10.0051
20′	10′	171.98	2.2354889	1.163	2.326	.291	.218	10.0056
30′	10½′	163.80	2.2143247	1.222	2.442	.306	.229	10.0062
40′	11′	156.37	2.1941477	1.280	2.558	.320	.240	10.0068
50′	11½′	149.58	2.1748701	1.338	2.674	.335	.251	10.0075
4° 0′	12′	143.36	2.1564155	1.396	2.790	.349	.262	10.0081
10′	12½′	137.63	2.1387167	1.454	2.906	.364	.273	10.0088
20′	13′	132.35	2.1217146	1.512	3.022	.378	.284	10.0095
30′	13½′	127.45	2.1053567	1.570	3.138	.393	.295	10.0103
40′	14′	122.91	2.0895961	1.629	3.254	.407	.306	10.0111
50′	14½′	118.68	2.0743911	1.687	3.370	.422	.317	10.0119
5° 0′	15′	114.74	2.0597040	1.745	3.486	.437	.328	10.0127
20′	16′	107.58	2.0317513	1.861	3.718	.466	.349	10.0145
40′	17′	101.28	2.0055032	1.977	3.950	.495	.371	10.0163
6° 0′	18′	95.67	1.9807654	2.093	4.181	.524	.393	10.0183
20′	19′	90.65	1.9573751	2.210	4.413	.553	.415	10.0204
40′	20′	86.14	1.9351943	2.326	4.644	.582	.437	10.0226
7° 0′	21′	82.06	1.9141055	2.442	4.875	.612	.459	10.0249
20′	22′	78.34	1.8940076	2.558	5.106	.641	.481	10.0274
40′	23′	74.96	1.8748128	2.674	5.336	.670	.503	10.0299
8° 0′	24′	71.85	1.8564447	2.790	5.567	.699	.525	10.0326
20′	25′	69.00	1.8388361	2.906	5.797	.729	.547	10.0353
40′	26′	66.36	1.8219279	3.022	6.027	.758	.569	10.0382
9° 0′	27′	63.92	1.8056676	3.138	6.257	.787	.591	10.0412
20′	28′	61.66	1.7900083	3.254	6.487	.816	.613	10.0444
40′	29′	59.55	1.7749082	3.370	6.717	.846	.635	10.0476
10° 0′	30′	57.59	1.7603298	3.486	6.946	.875	.657	10.0510

radius is 572.99. (It would be still better in using the metric system to have a new table calculated expressly for radius 572.958.) To get with very close approximation the corresponding dimensions for any other curve we divide by the degree designating the curve. Hence, for a 90° length of a metric 10° curve we should get a tangent or apex distance of 57.30 m. In the case of so sharp a curve the question arises whether this is sufficiently accurate for our purpose, and this question is answered by reference to the last column in the metric table. After moving the decimal point as above directed, we find 1.0051 for the 10° curve, showing that our 57.30 is in error by one-half of one per cent. To get exactly the distance required, multiply 5730 by 1.005, and we get 57.59, just as given in the metric table for the radius of the 10° curve. The same percentage correction is applicable to the other tabulated data as well as to the tangent or apex distance.

In computations like that discussed in the preceding paragraph, the 20-meter chord has the advantage over that of 100 ft. that it is a shorter length, and consequently the arc it subtends in any circle differs by a smaller percentage from the chord. Hence, the tabulated data above mentioned can be applied without requiring correction to a larger range of metric curves than of the curves used in the American foot practice. For example, observe that in the curves of 86.14 and 90.65 meters radius the percentage is less than one-quarter of one per cent. Between the two lies the 20° curve, as given in the American tables, with a radius of 287.9 ft., in which the 100-ft. chord subtends an arc of 100.5 ft., showing a percentage of one-half of one per cent. Accordingly, if we start 5,730 ft., the tabulated tangent or apex distance above cited for 90° length of an American 1° curve, and take one-twentieth of it for the corresponding dimension of the circle of 287.9 ft., radius, we have 286.5 ft., and must add 1.4 ft. to get the correct value equal to radius. On the other hand, suppose we had started with 573 meters as the tangent or apex distance in the metric 1° curve, to get the corresponding dimension of the circle of 86.14 meters radius observe that that circle is designated by the 20 m. chord angle of $6\frac{2}{3}$°; three-twentieths of 573 m. is 85.95 m., and to get the correct value equal to radius we must add 0.19 m., which is lees than half of 1.4 ft., and less than one quarter of one per cent.

Engineers accustomed to thinking of curves by their American designations may find it convenient in making mental comparisons to bear in mind that if any curve has its 20-m. chord angle multiplied by 3, the product is nearly the "degree" used to designate the curve in this country;

for 100 ft. is very little more than 3 dekameters. For instance, the curve last spoken of, having a radius of 86.14 m. and designated by the angle of $6\frac{2}{3}°$, is almost the same as the American curve of 20°, or $3 \times 6\frac{2}{3}°$. The number of 20 is given in the metric table in the column of minutes to be laid off per meter in staking out, as belonging to the curve of 86.14 m. radius; and all of the numbers in that column, instead of being read as minutes, might be regarded as the "degrees" designating American curves, in which case the corresponding figures of radii would be nearly the true value of meters of the radii of those American curves.

CHAPTER V.

Transition or Easement Curves.

Professor Arthur N. Talbot, of the University of Illinois, Champaign, Ill., has published a valuable paper on easement curves in *The Technograph*, 1890–91, from which we quote as follows:

THE TAPERING CURVE.

The Tapering Curve is a compound curve consisting of a series of circular curves of the same length, whose degree-of-curve increases by some constant difference up to the degree of the main curve. Thus, if the taper is 1° for each 30 feet, the approach from a tangent to a 6° curve will be made by 30 feet of 1° curve, 30 feet of 2° curve, 30 feet of 3° curve, 30 feet of 4° curve, and 30 feet of 5° curve, after which the 6° curve is run in.

If the degree of the main curve is not a multiple of the common difference of the tapers, at the end of the last full chord a fractional chord is used, proportional to the difference of the degree of the main curve and last taper. Thus, for a taper of 2° 30′ per 30 feet, an 8° curve would be reached by 30 feet of 2° 30′ and 30 feet of 5° curve, ending with 6 feet of 7° 30′ curve; since 8° is in excess of 7° 30′ by one-fifth of the change 2°-30′, one-fifth of a full chord is used.

In order to run the curve with the transit at the beginning of the tapering curve or at some corresponding point—thus saving settling at each P. C. C.—a table giving deflection angles to the different P. C. C.'s is used.

The tapering curve was introduced by Mr. William Hood, Chief Engineer of the Southern Pacific Railway, and has been extensively used on the Southern Pacific, Northern Pacific, Missouri Pacific, and other western roads. It makes a good transition curve, and does not vary much from the transition spiral. However, it lacks flexibility, this property being secured only by a wide range of tapers, necessitating many tables.

THE RAILROAD SPIRAL.

The Railroad Spiral, as developed by Wm. H. Searles, C. E., is a multi-form compound curve, differing from the tapering curve by using the central angles of the successive arcs as constant quantities, and varying the length of arc or chord to secure different spirals. The first arc has 10′ central angle, the second 20′, the third 30′, and so on to the end of the transition curve. Mr. Searles has published a little hand-book of tables and explanations for this curve. Tables of deflection angles with the transit at any chord point are given. These deflections are constant whatever the chord length. Thus, the deflection to the end of the 8th chord is 2° 07′, whether the length of curve be 8 × 10 feet or 8 × 21 feet, and the central angle subtended will also be the same. However, the degree-of-curve of the arcs will vary with a change in length of chord. This necessitates a set of tables giving the degree-of-curve for the last chord in the curve. As this is not an integral number, the one nearest the degree of the main curve is chosen. This is allowable, since it consists in compounding the last arc with the main curve. As several chord lengths with the corresponding number of chords will give about the same degree-of-curve, a variety of spirals for any main curve is secured. About sixty tables are given in Searles' "The Railroad Spiral," to which the student is referred for further information.

The "railroad spiral" approaches very near the true transition spiral. With the tables given, the calculations and field work are simple and rapid. Deflections for points between the chord points are found by interpolating in the tables, but only chord points may be used as transit-points. An objection has been made that the degree-of-curve for any chord is not an integral multiple of the number of the chord. This, however, is not of great importance.

THE PENNSYLVANIA METHOD.

The Pennsylvania Railroad uses 200 ft. of 30′ curve at the ends of a simple curve. For sharp curves 100 ft. of 1° curve is put in at either end. The super-elevation begins with zero at the P. C., and increases uniformly to the full amount at the beginning of the main curve. The claim is made that in this manner the complete super-elevation is attained while the car is on a light curve where the wheels keep to the outer rail, and that the shock incident to gaining the super-elevation while on the tangent is avoided. Of course the field work is simple. It is claimed that this method is very efficient, but it is open to criticism.

. . . . . .

THE TRANSITION SPIRAL.

The Transition Spiral is a curve whose degree-of-curve increases directly as the distance along the curve from the point of curvature.

Thus, if the spiral is to change at the rate of 10° per 100 feet, at 10 feet from the beginning of the spiral the curvature will be the same as that of a 1° curve; at 25 feet, as of a 2° 30′ curve; at 60 feet, as of a 6° curve. Likewise, at 60 feet, the spiral may be compounded with a 6° curve; at 80 feet, with an 8° curve, etc.

This curve fulfills the requirements for a transition curve. Its curvature increases at the distance measured around the curve. The formulas for its use are comparatively simple and easy. The field work and the computations necessary in laying it out and connecting it with circular curves are neither long nor complicated, and are similar to those for simple circular curves. The curve is extremely flexible, and may easily be adapted to the requirements of varied problems. The rate of change of degree-of-curve may be made any desirable amount according to the maximum curve used, or according to the requirements of the ground.

[For the formulas and tables deduced by Professor Talbot for the transition spiral we refer to the *Technograph*, 1890–91.]

When simple curves are left without transition curves, many track-men "ease" the curve by throwing the P. C. inward a short distance and gradually approaching the tangent a few rail-lengths away, while the main curve is reached finally by sharpening the curve for a short distance. Even this is better than no easement-curve.

The objection is sometimes raised that even if track is laid out with a carefully fitted spiral there would be no possibility of keeping it in place by the methods of the ordinary track-man. This identical objection could be made with the same force against carefully laid out circular curves, yet no engineer would recommend abolishing that practice. Even if, in re-lining, the transition curve is considerably distorted, it remains an easement, and will be in far better riding condition than a distorted circular curve. By marking the P. S. and the P. C. C. with a stake or post, with possibly on long spirals an intermediate point, the track-man will be able to keep the spiral in as good condition as though it were of uniform curvature.

Properly constructed spirals would frequently allow the use of sharper curvature—since the riding quality of curves may be the governing consideration in the selection of a maximum—and thus make a saving in construction. By fitting curves with proper transition spirals, roads

using sharp curves may partially relieve the objection of the public to traveling by their routes. The transition curve has, then, a financial value largely overbalancing its cost. The adoption of such curves by many of our principal railways proves their efficiency, and the future will see a much more general adoption.

LOCATION OF THE CUBIC PARABOLA.

By Professor Fred P. Spalding, Cornell University.

The necessity for using some form of easement curve, to connect the circular arcs upon railroad lines with the tangents, is now very generally recognized. Their adoption, however, has been greatly retarded by the difficulty met in attempting to reduce a satisfactory curve to a convenient form for ready use in the field.

Two methods of location are at present in use; first, by Froude's formulas for the cubic parabola as given by Rankine, the determination of the ordinates for setting out being made for each curve directly from the formulas; and second, the method of the railroad spiral as given by Searles and others, in which practically the same curve is located by means of deflection angles corresponding to various fixed chord lengths, the curve being varied by changing the chord length.

The object of this paper is to show how by a simple tabulation an approximation to the cubic parabola may be readily located in practice, either by ordinates or deflection angles, without the necessity of making calculations from formulas for each case, but at the same time allowing the use of chords of any lengths and the placing of stations wherever desired.

The formulas for this curve as given by Rankine are

$$y = \frac{4\,s\,x^3}{l^3}\ (1) \text{ and } s = \frac{l^2}{24\,R}\ (2)$$

in which s is the shift or offset $B\,C$ (Fig. 1) of the circular arc from the tangent, l is the length $A\,D$ (Fig. 1) of the easement curve, R is the radius of the circular arc, and y is the perpendicular offset from the tangent or from the circular arc to the easement curve, at any point distant x from the junction of the easement curve with the tangent or circular arc.

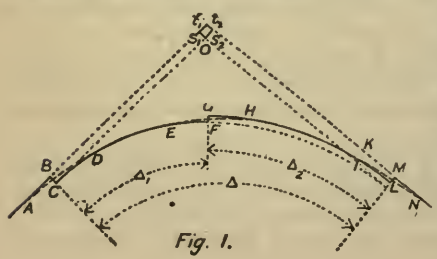


Fig. 1.

If it be desired to connect two curves of different degrees, the same form of easement curve may be employed, using only the portion of it which lies between the points where its radius of curvature equals the radii of the arcs to be connected. For this case, equation (1) applies directly, while for the value of the shift (2) becomes

$$s = \frac{l^2 (R_1 - R_2)}{24 R_1 R_2} \quad (3)$$

in which R_1 and R_2 are the radii of the circular curves.

LOCATION BY ORDINATES.

In order to locate an easement curve by this method, it is necessary to assume the value of either the length or the shift and calculate the other from formula (2) or (3). The shift may be fixed by topographical considerations, or the length may be determined by fixing the value for the ratio of the change in rail elevation to the length, authorities differing as to the best value to use for this ratio, but probably any value above the 1 in 300 recommended by Froude will give good results. Having thus found the value for the shift, it is to be laid off from the tangent toward the center of the proposed curve, and the circular arc run in from a parallel tangent at that distance from the main one. In other words, in locating a line upon which easement curves are to be used, the circular curves, instead of being placed in the usual manner tangent to the straight portions of the track, should be made tangent to parallel lines at a distance s from the main tangents, and in the same way the arcs of a compound curve should not be tangent to each other at the *P. C. C.*, but the arc of smaller radius should begin at a point on the common radial line distant s inward from the end of the larger arc.

The half-length of the easement curve is then laid off from the *P. C.* on the circular arc, and the point D (Fig. 1) so found will be the junction of the two curves; the half-length is also laid off on the main tangent from a point opposite the *P. C.* (B, Fig. 1) to find the point of tangency A (Fig. 1) of the easement curve.

Having determined these points, different values of x less than $\frac{l}{2}$ substituted in formula (1) will give values of y to be laid off from points distant x from D on the circle, and from A on the tangent, to determine points on the easement curve.

Tables may now be constructed on these formulas which will give directly the value of the ordinates to be used in placing the curve on the ground, and as experience has shown that comparatively few variations

will be necessary to meet all cases in practice, such tables need not be very extended to answer all requirements.

In order to construct such a table, suppose that the curvature is to increase 1° for every 50 *ft.* of distance, then for a 10° curve, $l = 500$ *ft.* and $s = \frac{l^2}{24R} = 18.16$ *ft.*; substituting these values in (1), if $x = 10$ *ft.*, $y = .000581$ *ft.* To find other values of y corresponding to different values of x, we notice that y varies as the cube of x, and thus construct the last column of Table 1.

In order to extend the table to other curves in which the curvature varies differently, we notice that, combining formulas (1) and (2), y varies as $\frac{R}{l}$ for x constant, or, approximately, inversely as the ratio between length and curvature.

In the table, the offset is given for every 10 *ft.* of length. Intermediate values may be found by interpolation, without sensible error.

To illustrate the use of the table in locating a curve, suppose that two tangents are to be connected by a compound curve composed of an arc of 5° and one of 8° curvature, and that the changes of radius are to be eased by curves, in which the curvature increases 1° for every 40 *ft.* of distance from the tangent.

First the circular curves must be located as shown by the full lines (Fig. 1) with the proper shift from the tangents and from each other.

For an increase of curvature of 1° in 40 *ft.*, the length of easement curve for an 8° will be 320 *ft.*

When $x = \frac{l}{2}$ (formula 1), $y = \frac{s}{2}$, and going into the table with $x = \frac{l}{2} = 160$, we find $y = 2.97 = \frac{s}{2}$, hence $BC = s = 5.94$ *ft.* In the same way $ML = s = 1.46$ *ft.* may be found for the 5°. For the connection between the two circular arcs, $l =$ the difference of lengths of the curves required to connect the two arcs with tangent $= 320 - 200 = 120$ *ft.* and as before $\frac{s}{2} = .15$ *ft.* may be taken from the table.

Now to locate the curve AD, suppose that the *P.C.* of the circular arc comes at sta. 10 + 65 and that it is desired to mark 50 *ft.* stations on the easement curve, these stations having first been located on the tangent AB and the arc CD. As the half-length of the easement curve is 160 *ft.*

the *P.E.C.*, or point where the easement curve leaves the tangent will be at sta. 9 + 05. The quantities necessary to lay out the easement curve may then be tabulated as follows, taking values of y to nearest tenth foot.

Sta. 9 + 05 *P.E.C.*	$x = 0$,	$y = 0.0$,	Measured	from	tangent.
9 + 50	$x = 45$,	$y = 0.1$,	"	"	"
10	$x = 95$,	$y = 0.6$,	"	"	"
10 + 50	$x = 145$,	$y = 2.2$,	"	"	"
10 + 65 *P.C.*	$x = 160$,	$y = 3.0$,	"	"	"
11	$x = 125$,	$y = 2.4$,	"	"	Curve *CD*.
11 + 50	$x = 75$,	$y = 0.3$,	"	"	"
12	$x = 25$,	$y = 0.0$,	"	"	"
12 + 25 *P.O.*	$x = 0$,	$y = 0.0$,	"	"	"

The location of this curve is thus seen to be a very simple matter; calculations for the circular arcs may be made in the usual manner, and the use of the easement curve introduces no new element into their location, save the necessity of laying them tangent to lines parallel to the main tangents.

The tangent distance on main tangent to *P.E.C.* may be found from the formula $T_E = T + \frac{l}{2} + t$, in which T is the tangent distance for the curve as ordinarily run, $\frac{l}{2}$ the half-le h of the easement curve, and t a correction due to shifting the point of intersection (see Fig. I). For a simple curve with the same shift at both ends $t = s \tan \frac{1}{2} \triangle$. For a simple curve with different values of s at the two ends, $t_1 = \frac{s_2}{\sin \triangle} - s_1 \cot \triangle$ and $t_2 = \frac{s_1}{\sin \triangle} - s_2 \cot \triangle$. For a compound curve, if s_3 be shift between circular arcs, s_2 that of the curve of larger, and s_1 of the curve of smaller radius from the tangent, $t_1 = \frac{s_2 + s_3 \cos \triangle_2}{\sin \triangle} - s_1 \cot \triangle$ and $t_2 = \frac{s_1}{\sin \triangle} - (s_2 + s_3 \cos \triangle_2) \cot \triangle + s_3 \sin \triangle_2$.

LOCATION BY DEFLECTION ANGLES.

If the values of x in Table I be supposed to be measured on chords of the easement curve; and if a be the angle between the tangent and the chord to any point distant x from the *P.E.C.*, then $\sin a = \frac{y}{x}$, and if a table of the values of a for each curve be made, the curve may be located on the ground in the ordinary manner by deflections from the tangent.

To construct this table, take a value of y and divide it by the corresponding value of x, and find from a table of sines the angle of deflection, then since y varies as the cube of x, $\frac{y}{x}$ varies as the square of x, and as for small angles the sine is approximately as the angle, the various angles may be taken as varying with the squares of their distances. In this manner any column of Table II. may be constructed, then any other column may be found, as in the case of the ordinates in Table I., by considering that for constant values of x, $\frac{y}{x}$ varies inversely as the ratio between the length of curve and the change in curvature.

As the length of easement curve is not exactly equal to the sum of the lengths measured on the tangent and circular arc, a correction must in some cases be applied, when the curve is to be located by this method. This correction which we will call z, is to be substracted from $\frac{l}{2}$ to determine the distance to be measured back on the tangent from the *P.C.* to find the *P.E.C.* Applying this correction to the formula for tangent distance we have $T_E = T + t + \frac{l}{2} - z$. Values of z are given in Table III., found by calculating the co-ordinates of the ends of the easement curve by the two lines.

In order to lay out a curve by this method, we first locate the *P.E.C.*, and placing the instrument at that point, turn off the deflections and lay out the curve by chords of any desired length, interpolating between the numbers in the table for the angle to any point not given. To pass from a circular arc to the tangent, or to an arc of greater radius, the *P.O.*, or point of osculation, is located at a distance $\frac{l}{2}$ from the *P.T.*, and then as the deviation of the easement curve from the circular arc is the same as from the tangent, the deflection to any point of the easement curve distant x from the *P.O.* is equal to the deflection for the circular arc for the same distance *minus* the deflection for that distance as given in Table II., or in passing from a curve of larger to one of smaller radius, the tabular deflection must be added to the circular deflection.

As an illustration of this method suppose that it be required to locate the curve of Fig. 1 by means of deflection angles. It will not be necessary in this case as in the former one to first locate the circular arcs, but, having found the *P.E.C.*, set the instrument over that point, turn off the

deflections, and run in the curve in the ordinary manner. The deflections for the first easement curve may be taken directly from Table II., as given below:

Sta.	9 + 05 *P.E.C.*	$x =$ 0	
	9 + 50	$x =$ 45,	$a = 0°05'$
	10	$x =$ 95,	$a =$ 22′
	10 + 50	$x =$ 145,	$a =$ 52′
	11	$x =$ 195,	$a = 1°35'$
	11 + 50	$x =$ 245,	$a = 2°30'$
	12	$x =$ 295,	$a = 3°37'$
	12 + 25 *P.O.*	$x =$ 320,	$a = 4°16'$

Having located the *P.O.* and set the instrument there, we turn to tangent by deflecting from a backsight on the *P.E.C.* an angle equal to twice the last forward deflection, 2 (4° 16′) = 8° 32′. In other words, the angle between the tangent at any point of the easement curve, and the chord connecting that point with the *P.E.C.* is equal to twice the angle between the tangent at the *P.E.C.* and the same chord.

To locate the easement curve connecting the circular arcs, having located the first arc *DE*, (Fig. 1) and found the *P.O.* (*E*) at which the second easement curve begins, suppose this point to come at station 17 + 22.5; the deflections for this easement curve from the circular arc *EF* will then be the same as those of the first curve from the tangent *AB*, or the deflections from the curve *EH* from the tangent at *E*, will equal the deflections for the arc *EF*, minus the deflections from Table II. for the easement curve, and may be tabulated as follows:

Sta. 17+22.5 *P.O.*	$x=$ 0		
17+50	$x=$ 27.5,	deflection	$=1°06'-0°02'=1°04'$
18	$x=$ 77.5,	"	$=3°06'-0°15'=2°51'$
18+42.5 *P.O.*	$x=$120.0,	"	$=4°48'-0°36'=4°12'$

To find the tangent at 18+42.5 (*P.O.*), turn from the last chord an angle = deflection for 120′ of 8° curve, (4°48′) *minus* twice (deflection for 120′ of easement curve), (2×36′=72′)=3°36′, or this angle may be found thus; deflection for 120′ of 5° curve, (3°00′) *plus* deflection for 120′ of easement curve, (36′) = 3°36′.

In the same manner having run the 5° circular arc, we can tabulate the

deflections necessary to connect it with the tangent, supposing the *P.O.* to be at sta. 23 + 13.5.

23+13.5 *P.O.*	$x=$ 0		
23+50	$x=$ 36.5,	deflection	$=0°55'-0°03'=0°52'$
24	$x=$ 86.5,	"	$=2°10'-0°19'=1°51'$
24+50	$x=$136.5,	"	$=3°25'-0°47'=2°38'$
25	$x=$176.5,	"	$=4°40'-1°27'=3°13'$
25+13.5 *P.E.T.*	$x=$200,	"	$=5°00'-1°40'=3°20'$

Then turn to the tangent at *M*, by deflecting from the last chord, one-half the last deflection, $\frac{1}{2}(3°20') = 1°40'$ = the deflection for 200 ft. of the easement curve.

The deflection from the *P. E. C.* to any point x of the easement curve is equal to one-third of the deflection for the same length of the circular arc, whose radius is equal to the radius of curvature of the easement curve at the point x; also, the difference between the circular deflections at any two points of an easement curve, for a length equal to the distance between the points, is equal to three times the easement deflection for the same length.

In case it be necessary to set the instrument at any intermediate point upon the curve, this enables us to readily find the deflections for the circular arc at that point. Thus, if we desire to set the instrument at station 24 in the above example, we first turn to tangent at 24 by deflecting $2° 10' - 2 \times 19' = 1° 32'$ from the last chord.

Then the deflection for 86.5 *ft.* of the circular arc, whose radius equals the radius of curvature of the easement curve at station 24 is $2° 10' - 3 \times 19' = 1° 13'$, and the deflection for 50 *ft.* is $\frac{50}{86.5}(1° 13')$ $= 42'$ or, as the point 24 is 113.5 *ft.* on the easement curve from the tangent, easement deflection for 113.5 *ft.* is 32′ (Table II.), and $32' \times 3 \times \frac{50}{113.5} = 42'$.

Then the deflections from tangent at 24 for the remainder of the curve would be

Sta. 24	$x =$ 0,		
24 + 50	$x =$ 50,	deflection =	$42' - 06' = 0°36'$
25	$x =$ 100,	" =	$1°24' - 25' = 0°59'$
25 + 13.5 *P.E.T.*	$x =$ 113.5,	" =	$1°36' - 32' = 1°04'$

As will be seen by an inspection of the tables, the few curves tabulated

afford considerable range for choice of a curve for any particular case, and will give considerable elasticity to the work of placing the location by allowing the use of various shifts. Tables affording a much larger choice may readily be constructed, and will occupy but a small space while answering all the requirements of any practical case.

NOTE.—It is to be noticed that the two methods of location above outlined do not give exactly the same curve, and hence are not interchangeable except within the limits where z is zero. Outside these limits the length of the curve located by ordinates will exceed the distance measured upon the tangent and circular arc by a quantity approximately equal to z. The values of z will vary somewhat with the use of different chord lengths in location. In a case where extreme accuracy is required a small correction should also be applied to the shift; within the limits covered by these tables, however, this correction would be inappreciable for any ordinary work. Evidently the methods used for the deflections is only applicable to small angles, as it is an approximation and not theoretically exact, and if continued to larger angles the deflections will no longer equal one-third of the central angle, and corrections must be applied. Most cases in practice will, however, probably be well within the limits of the tables given.

SPECIAL CASES.

It is frequently necessary to replace circular curves already in use by others connecting the same tangents and passing through certain points whose positions are known. All such cases may be met by the foregoing methods, the solution in each case varying with the data given.

As an illustration take one of the most common cases. Let ABC (Fig. 2) be an 8° circular curve 700 ft. long, which is to be replaced by a new circular arc, passing through the same vertex (B) and joined to the same tangents by easement curves in which the curvature change 1° for each 30 *ft.* of distance. The shift for the 8° curve from Table I. is 3.3 *ft.*, but the new arc will be of less radius than the 8° and the shift greater; assume it at 4.0 *ft.*, then the external distance (DB) of the 8° curve $= R.\ ex.\ sec\ \frac{1}{2}\triangle$, $= 716.779 \times .13257 = 95.02\ ft.$

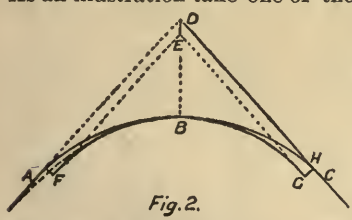


Fig. 2.

$DE = GH\ sec\ \frac{1}{2}\triangle = s\ sec\ \frac{1}{2}\triangle.$

BE (the external distance for the new arc) $= BD - DE = 95.02 - 4 \times 1.13257 = 90.49$ *ft.*, and the radius of the new arc $= \frac{BE}{ex.\ sec\ \frac{1}{2}\ \Delta} = \frac{90.49}{.13257} = 682.6$ *ft.* or the rate of curvature of the new arc is 8° 24′.

The length of easement curve to vary 1° in 30 *ft.* is then 252 *ft.*, the half-length 126 *ft.*, and (from the table) the half-shift is 1.95 or $s = 3.9$, which shows that our assumption of 4.0 *ft.* for the shift is sufficiently accurate; in case it were not, it would be necessary to try a new one.

Now from B, the 8° 24′ curve may be located ending at F and G, or the tangent distance may be computed from the formula, and the *P.E.C.* located after which the curve may be placed by the use of the tables as in the former cases.

If it be desired to shift the vertex of the new curve any distance either outward or inward from the original curve, it will simply be necessary to subtract such distance from or add it to the external distance in finding the radius of the new curve.

TABLE I.—ORDINATES FOR LOCATING THE CUBIC PARABOLA.

Values of x.	Curvature changes 1° for every						
	20 feet.	25 feet.	30 feet.	35 feet.	40 feet.	45 feet.	50 feet.
10 feet.	0.00 feet.	0.00 feet.	0.00 feet.	0.00 feet.	0.00 feet.	0.00 feet.	0.00 feet.
20 "	0.01 "	0.01 "	0.01 "	0.01 "	0.01 "	0.00 "	0.00 "
30 "	0.04 "	0.03 "	0.03 "	0.02 "	0.02 "	0.02 "	0.02 "
40 "	0.09 "	0.07 "	0.06 "	0.05 "	0.05 "	0.04 "	0.04 "
50 "	0.18 "	0.14 "	0.12 "	0.10 "	0.09 "	0.08 "	0.07 "
60 "	0.31 "	0.25 "	0.21 "	0.18 "	0.15 "	0.14 "	0.13 "
70 "	0.50 "	0.40 "	0.32 "	0.28 "	0.25 "	0.22 "	0.20 "
80 "	0.74 "	0.60 "	0.49 "	0.42 "	0.37 "	0.33 "	0.30 "
90 "	1.06 "	0.85 "	0.70 "	0.60 "	0.53 "	0.47 "	0.42 "
100 "	1.45 "	1.16 "	0.97 "	0.83 "	0.73 "	0.65 "	0.58 "
110 "	1.93 "	1.55 "	1.29 "	1.10 "	0.96 "	0.86 "	0.77 "
120 "	2.51 "	2.00 "	1.67 "	1.43 "	1.25 "	1.12 "	1.00 "
130 "	3.19 "	2.50 "	2.13 "	1.83 "	1.60 "	1.42 "	1.28 "
140 "	3.98 "	3.20 "	2.66 "	2.29 "	2.00 "	1.77 "	1.60 "
150 "	4.90 "	3.92 "	3.27 "	2.80 "	2.45 "	2.18 "	1.96 "
160 "				3.39 "	2.97 "	2.64 "	2.38 "
170 "				4.08 "	3.57 "	3.17 "	2.85 "
180 "				4.81 "	4.24 "	3.76 "	3.38 "
190 "				5.69 "	4.98 "	4.43 "	3.98 "
200 "				6.64 "	5.81 "	5.16 "	4.61 "
210 "						5.98 "	5.38 "
220 "						6.87 "	6.19 "
230 "						7.85 "	7.07 "
240 "						8.92 "	8.03 "
250 "						10.09 "	9.08 "

TABLE II.—DEFLECTION FOR LOCATING THE CUBIC PARABOLA.

Values of x.	Curvature changes 1° for each						
	20 feet.	25 feet.	30 feet.	35 feet.	40 feet.	45 feet	50 feet.
10 feet	0° 00′	0° 00′	0° 00′	0° 00′	0° 00′	0° 00	0° 00′
20 "	02	02	01	01	01	01	01
30 "	05	04	03	03	02	02	02
40 "	08	06	05	04	04	03	03
50 "	13	10	08	07	06	06	05
60 "	18	15	12	10	09	08	07
70 "	25	20	16	14	12	11	10
80 "	32	26	21	19	16	14	13
90 "	40	32	27	23	20	18	16
100 "	50	40	33	29	25	22	20
110 "	1	48	40	34	30	27	24
120 "	00	58	48	41	36	32	29
130 "	12	1 08	56	49	42	38	34
140 "	25	18	1 05	56	49	43	39
150 "	38	30	15	1 04	56	50	45
	52						
160 "	2 08	42	25	13	1 04	57	51
170 "	25	56	36	23	12	1 04	58
180 "	42	2 10	48	33	21	12	1 05
190 "	3 00	24	2 06	43	30	20	12
200 "	20	40	13	54	40	29	20
210 "	40	56	27	2 06	50	38	28
220 "	4 02	3 14	41	17	2 01	47	37
230 "	25	32	56	31	12	58	46
240 "	48	50	3 12	45	24	2 08	55
250 "	5 12	4 10	28	59	36	19	2 05
		30					
260 "	38	52	45	3 13	49	30	15
270 "	6 05		4 03	29	3 02	42	26
280 "	32	5 14	21	44	16	54	37
290 "	7 00	36	40	4 00	30	3 07	48
300 "	7 30	6 00	5 00	17	45	20	3 00
310 "				4 34	4 00	3 33	3 12
320 "				43	16	48	25
330 "				5 11	32	4 02	38
340 "				30	49	17	51
350 "				50	5 06	32	4 05
360 "					24	48	19
370 "					42	5 04	34
380 "					6 01	21	49
390 "					20	38	5 04
400 "					40	55	20
410 "						6 15	36
420 "						32	53
430 "						41	6 10
440 "						7 10	27
450 "						30	45
460 "							7 03
470 "							22
480 "							40
490 "							8 00
500 "							20

TABLE III.—VALUES OF z.

Minus Correction for Tangent Distance of Easement Curve Located by Deflection Angles

Degree of Curve.	Curvature changes 1° for each						
	20 feet.	25 feet.	30 feet.	35 feet.	40 feet.	45 feet.	50 feet.
6 deg.					0.1 feet.	0.1 feet.	0.1 feet.
7 "			0.1 feet.	0.1 feet.	0.2 "	0.2 "	0.3 "
8 "		0.1 feet.	0.2 "	0.3 "	0.4 "	0.5 "	0.6 "
9 "	0.1 feet.	0.2 "	0.4 "	0.5 "	0.7 "	0.8 "	1.1 "
10 "	0.2 "	0.3 "	0.6 "	0.8 "	1.0 "	1.3 "	1.7 "
11 "	0.3 "	0.5 "					
12 "	0.4 "	0.7 "					
13 "	0.6 "						
14 "	0.8 "						
15 "	1.1 "						

ELEVATION OF OUTER RAIL ON CURVES.

The elevation of the outer rail is constant throughout the curve. Its theoretical amount (see "Henck's Pocket Book") is $\frac{g\,v^2}{32.2\,R}$, in which g is the gauge, v is the velocity of the train, and R is the radius of the curve. If g is 4.7 and v is 40.44 or 27.57 miles per hour, this reduces to $\frac{238.7}{R}$, or, if the elevation is in inches and the radius in feet, to $\frac{2,864}{R}$. But this numerator is the radius of a two-degree curve, from which the rule is deduced which is adopted on many railroads: "Elevate the outer rail one-half an inch for each degree of curve." Thus, for a two-degree curve elevate one inch, and for a six-degree curve, elevate three inches.

If a circular curve starts directly from a tangent, theory requires an abrupt elevation at the point of curvature. As this, however, is impracticable, the elevation is usually run out on the first rail (or the first two) from the point of curvature, the rail being at the height of the elevated rail at one end, and at the height of the opposite rail at the other end. To avoid the theoretical difficulty of the sudden elevation of the outer rail, parabolic curves have been proposed, the radius of curvature at the beginning of the curve being so long as to be practically infinite, which would require no elevation; and as the radius became gradually shorter to the middle of the curve, the outer rail could be proportionately elevated. The additional labor involved in laying out the curves, and giving this

variable elevation, has prevented the general introduction of parabolic curves in this country. However, the end of making the elevation proportional to the curvature gradually is accomplished by putting in, at each end of the curve, what is called a "curve of adjustment" when the rails are being laid, which is an "elastic curve," and is laid out by offsets from the centre-line stakes, the latter being set on tangents and circular curves. The method of laying out the elastic curve is given in the preceding pages. It seems to be the English practice to obtain the proper elevation of the outer rail by raising the outer rail one-half of the proper amount and depressing the inner rail by the same amount. In the United States, however, it is generally all put in the outer rail, the inner rail carrying the grade of the road.

CHAPTER VI.

Earthwork and Masonry.

ESTIMATING OVERHAUL IN EARTHWORK BY MEANS OF THE PROFILE OF QUANTITIES.

By S. B. Fisher, Chief Engineer of the Minneapolis, St. Paul & Sault Ste. Marie Ry., Minn.

No facile, practical and accurate method of calculating the overhaul of earthwork is as yet in common use. The problem itself, consisting of finding the relations between the centers of gravity of known volumes in known positions may be, from the mathematician's point of view, a comparatively simple one; but such a lack of readiness to solve it has the engineer shown that many a contract has been executed with the privilege of wasting and borrowing at the end of the haul. This practice results at times in waste of energy by the contractor, and still oftener in the waste of money to the other party to the contract. By the system of wasting and borrowing, material is paid for at the full price of excavation beyond the haul, but, with the judicious use of overhaul, in many cases the material may be hauled half a mile before its price is doubled. When, from the increase of the traffic of a railroad, for example, it becomes necessary to grade for a second track, and in so doing to remove material wasted on the margin of a cut into an adjoining borrow pit along the neighboring fill, where it ought to have been deposited in the first place, it neither increases the respect of the later engineers for their predecessors, nor is it a credit to the profession.

Overhaul as commonly worked out is done in an approximate manner with the ordinary profile and the volumes in excavation and embankment. It takes longer to work it out with the "Profile of Quantities," of

which a short example is engraved, but it is done completely and accurately.

The method of the profile of quantities was originated by Brückner, a Bavarian engineer. It was presented by Cuhlman in his "Graphical Statics" in 1868, and translated from that by F. Reineker, then (1871–3) Principal Assistant Engineer of the Pennsylvania Co , at Pittsburg, Pa , for the use of his department. This translation was procured there by the writer, and the method adapted to American practice in a great variety of railway work, and is here given with an example of work as actually executed.

The subject is presented, for convenience and clearness, in three steps—

1st. *The Compilation of the Data.* 2d. *The Plotting of the Profile.* 3d. *The Taking Off of the Results.*

I. COMPILATION OF THE DATA.

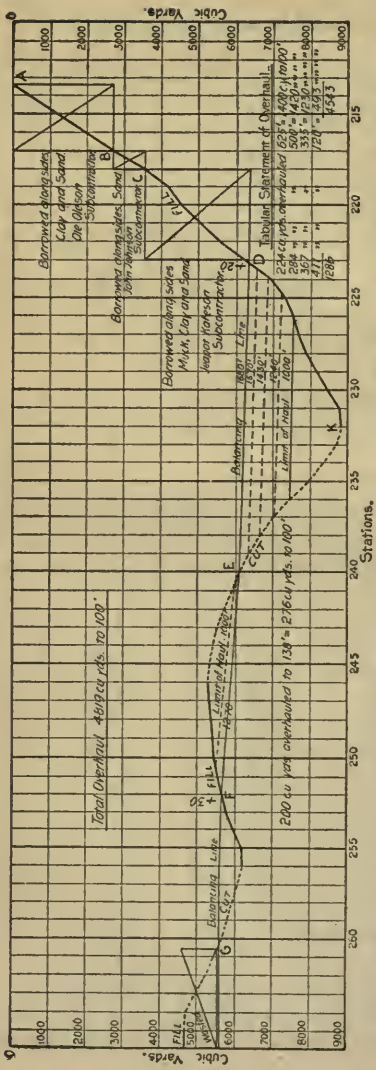
The paper containing the data is ruled in five vertical columns, as in the following sample table :

SAMPLE TABLE OF COMPUTATIONS FOR CONSTRUCTING "PROFILE OF QUANTITIES."

O. & S. W. R. R. data for Profile of Quantities, Section 5, Oct. 1, 1889.

Sta.	Increments.		Ordinates.		Sta.	Increments		Ordinates.		Sta.	Increments.		Ordinates.	
	+	−	+	−		+	−	+	−		+	−	+	−
213+34	...	....	....	.....	1	...	317	....	8,804	9	....	83	..	5,425
214	....	370	....	370	2	....	83	....	8.887	250	....	78	....	5,503
5	....	843	....	1,213	3	161	..	....	8,726	1	...	65	....	5,568
6	....	779	....	1,991	4	328	....	....	8,398	2	....	70	....	5,638
7		724	....	2,715	5	464	....	..	7,934	3	...	124	....	5,762
8	....	902	....	3,617	6	493	....	....	7,441	4	....	181	....	5,943
9	....	570	. .	4.187	7	411	..	....	7,030	5	....	189	....	6,132
220	....	391	....	4,578	8	367	....	....	6,663	6	....	85	....	6,217
1	...	457	....	5,035	9	284	....	....	6,379	7	55	....	....	6,052
2	....	535	....	5,570	240	224	...	....	6,155	8	156	....	. ..	5 896
3	....	678	....	6,248	1	200	....	....	5.955	9	102	....	..	5,791
4	...	723	....	6.973	2	189	....	....	5,770	0	146	....	....	5,658
5	..	344	....	7,317	3	185	.	....	5,585	1	206	....	....	5,452
6	....	193	....	7,510	4	156	....	....	5,429	2	237	....	....	5,215
7	....	156	....	7,666	5	102	....	....	5,327	3	250	....	.. .	4,965
8	..	244	....	7.910	6	59	...	....	5,258	4	274	...	....	4,691
9	....	221	...	8,131	7	....	14	....	5,272	5	47	....	....	4,644
230	....	356	....	8,487	8	....	70	....	5,342	6	....	6	....	4,650

The first column contains the station numbers. In practice the elemental volume is the total excavation or embankment in a full station, whether the station distance is 100 ft., 66 ft., or a number of metres.



Plusses are not used, excepting at an occasional beginning or end of a subsection, although the system is flexible enough to apply to any regu lar or irregular subdivision of these elemental volumes.

In columns 2 and 3 are now entered the total *increments* or volumes of earthwork in excavation or embankment in successive stations. When excavation and embankment both occur within the limit of the same station the net amount only need be entered. If there is a special price for casting within the station another column may be introduced for it. Excavation is considered plus and embankment minus. The latter may be entered in red ink.

Columns 4 and 5 are now filled up by algebraic addition of columns 2 and 3. The ordinate at any point of the "Profile of Quantities" is equal to the algebraic sum of the volumes as far as to that point, and should be verified by use of this principle, at convenient points, as the summation proceeds.

II. THE PLOTTING OF THE PROFILE.

The horizontal part of the plotting is the same as used in the ordinary profile, and it may be made on the same sheet of paper; but for the vertical part, instead of elevations being referred to a datum plane, at or below the lower edge of the profile paper, we have an initial line or axis of abscissas, lo-

cated some where on the profile, from which the ordinates are measured above for plus and below for minus. Connecting the ends of these ordinates, we have a broken line, which in mathematical language may be called a curve, resembling somewhat an ordinary profile, but wholly different therefrom, composed of the elements between the successive stations.

If the increment, by the use of which any ordinate is formed from the previous one, is positive, this element of the curve will incline upward, will indicate excavation, and be shown by a dotted or blue line. If the increment is negative the element of the curve will incline downward, will indicate embankment and be shown in red or by a solid line. So that excavation on the profile of quantities is always shown by an ascending dotted or blue line, and embankment by a descending solid or red line.

We now consider the *balancing line.* Some points of this line are always fixed by the patent conditions of the work, and occasionally all points are so fixed, but very often some points on it are indeterminate at first, so that each section is very likely to be a little problem by itself. The functions of the balancing line will most clearly be seen by referring to the engraved sample profile. We have here the first point of it, *A*, the beginning of the section; *B*, the end of Ole Olson's job; *C*, the end of John Johnson's job; *D*, the end of Teapot Kofeeson's job; *E*, at station 240, the dividing point between backward and forward hauls in the cut; *F*, station 252+30; *J*, junction point of forward and backward hauls in the fill; *G*, the point where waste commences in the second cut, and *H*, the end of the section.

III. THE TAKING OFF THE RESULTS.

From *A* to *D* there is no over haul, but the nature of the material and any other items can be conveniently recorded there. The fill between *D* and *K* is made from the cut between *K* and *E*. We first fix the position of the limit of haul, which here comes between stations 226 and 236, and then draw the intervening lines of over haul to each point of flexure of blue and red lines. We now read the elements of the cut between these lines of haul, from the profile *m*, or if we desire great accuracy, from the data prepared for plotting the profile *n*, and tabulate them. Each of these elements multiplied by its respective distance overhauled will give equivalent quantities overhauled to one station; as for example,

$$224\ cy \times \frac{1{,}680 + 1{,}570}{2} - 1{,}000 = 224 \times 6.25 = 1{,}390.$$ The sum of these partial products will give the total overhaul for the cut. The tabulation

should always be verified, by seeing that the sum of the elements of the blue or red curve, as the case is, is equal to the difference between the extreme ordinates.

If *E K* is rock or *D K* is a sink hole, the line *E D* will be inclined, and should be prolonged to an intersection with the horizontal through *K*. This intersection then becomes a pole, through which the lines of haul are drawn. The method is so flexible it can be applied to anything which can be executed in earthwork, and in addition gives a record of what has been done. It is also used to make the preliminary distribution of material before the work is begun.

NOTE.—For the further discussion of this subject see Engineering News of April 4, 1883, and March 14, 1891.

EXPANSION OF ROCK IN EMBANKMENT.

The following are data of an accurate test made at Boulder, Colo., in 1882 on expansion of solid rock from cut to embankment. The point chosen offered these advantages: material all solid rock, free from an overlying earth; surface uniform, admitting of accurate measurement; no possible settling of the embankment, as it was directly on granite cow-pastures; volume of the work 9,000 cubic yards in 400 ft. lengths, reducing wastage from blasts to a minimum, and lastly, its location being such that it was seen several times every day. Results as follows: Rock in excavation and borrow pit measured in place 3.596 yds.; the same material, measured in embankment, yielded 5,337 yds., or an expansion ratio of 1 : 1.512.

NOTES ON EARTHWORK.*

In making the final estimates of the St. Gothard Railroad, the quantities in cut were increased by 3% in earth and 8% in rock, to equalize the amounts needed for embankments.

In the levee work, under the direction of the writer, the following proportions were observed:

9,398 cubic yards in cut gave 9,470 in fill (ground: heavy adobe, measured three weeks after finished).

10,000 cubic yards in cut gave 10,290 in fill (ground: adobe in sandy loam).

29,000 cubic yards in cut gave 30,330 in fill (ground: the same as last).

53,350 cubic yards in cut gave 58,350 in fill (ground: sandy loam with small amounts of adobe and hard pan; this is the largest increase found).

* Read by the late Geo. J. Specht before the Technical Society of the Pacific Coast, May 1, 1885.

202,634 cubic yards in cut gave 208,915 in fill (this represents the work of three months).

The conclusion is, that no general coefficient can be established to express the proportion of earth or rock in place to earth or rock in fill. It is different with different kinds of material and with the different methods of building the embankments.

A. Von Kaven, President of the Royal Polytechnic Institute in Aix-la-Chapelle, says in his book on "road building":

"The volume of an embankment and its height are different at different times. European experience is road building is that, after the fill is finished, the earth used therein occupies a larger space than in the ground:

In clay and loam	1-48 more.
In soft sandstone	1-32 "
In hard clay	1-20 "
In rock	1-13 to 1-10 "

"During the construction of the Rhine-Nahe Railroad it was observed that the increase in bulk from cut to fill was in the beginning 25 per cent. in rock, but when from one-quarter to one-third of the total bulk of the embankment was built of clay; put in simultaneously with the rock, the final increase in embankment, after the same was finished, was only 9 per cent. There are certain kinds of earth and certain conditions during the time of building, when the embankment occupies less space than the earth measured in place. For instance, if the earth is wet, or if it is tamped, etc. The French engineer, Graeff, says that 1 cubic metre of rock measured 1.5 to 1.6 whenever in fill, but as considerable earth was used with it to fill the intermediate spaces, 1 cubic metre cut made 1 cubic metre fill in a general average.

"In building the Marne-Rhine canal the loose earth was carefully tamped and 1 cubic metre embankment required 1.10 to 1.25 cubic metre in cut. He advises, therefore, not to count on any difference, but to accept cut and fill alike, and allow only in very light sand a decrease of one-tenth in fill.

"According to a series of observations—

"100 cubic feet of loose sand make 115–120 cubic feet in fill.

"100 cubic feet of clay and coarse sand make 122 cubic feet in fill.

"100 cubic feet of hard clay, lias, make 124 cubic feet in fill.

"100 cubic feet of clay mixed with cobble-stones make 126 cubic feet in fill.

"100 cubic feet of decomposed rock, solid gravel banks, make 128 cubic feet in fill.

"100 cubic feet of rock (can be picked) make 130 cubic feet in fill.

"100 cubic feet of rock, requiring blasting, make 134–150 cubic feet in fill."

Henz, the author of a Manual on Earthwork, states as the result of a large number of observations of actual work, that the permanent increase in volume from cut to fill is—

In sandy soil	1-1.5	per cent.
In clay and light soil	3	"
In marl	4-5	"
In hard clay	6-7	"
In rock	8-12	"

J. C. Trautwine, in his "Pocket-Book," says: "Although earth when first dug and loosely thrown out, swells about $\frac{1}{5}$ part, so that a cubic yard in place averages about $1\frac{1}{5}$ or 1.2 cubic yards when dug; or 1 cubic yard when dug is equal to $\frac{5}{6}$ or 0.8333 of a cubic yard in place; yet when made into embankment it *gradually* subsides, settles or shrinks into a less bulk than it occupied before being dug."

EARTHWORK COMPUTATION.

A. M. WELLINGTON.

1. Compute solidities by averaging end areas and use the results for all preliminary purposes, monthly estimates, etc.

2. At any time before the final estimate, substract the center heights only from each other of those solids only which differ three feet or more in center height.

3. Determine a correction to be applied to each of such solids from a tabulation of the following formula:

$$\text{Correction in cu. yds.} = \frac{(c - c')^2 r}{6} \times \frac{l}{27.}$$

in which c and $c\,c'$ = center heights, r = ratio of slope and l = length of solid = 100 feet for purposes of the table.

(Such a table can be made in a few minutes, as it is required only from 3 to 10 or 12 feet ranging by tenths.)

4. Determine the sum of these corrections for any given section and deduct them in gross from the end area solidity, for final estimate purposes.

LEVEE CONSTRUCTION.

The following methods of construction are those adopted by the Board of Mississippi Levee Commissioners and their Chief Engineer:

The ground to be occupied by the levee must first be cleared of trees, stumps, logs, trash, weeds and all perishable matter; the trees and stumps being cut level with the surface of the ground. The entire surface must then be thoroughly broken with a spade or plow, in order to form a bond with the earth deposited. Then a muck ditch must be cut on the river side of the center line: all stumps and roots crossing it being carefully taken out and removed beyond the base of the levee. As each section of a mile in length of the entire levee is thus cleared, broken, and ditch cut, the engineer sets the side stakes of the base of the levee; the muck ditch is then filled in with buckshot earth or clay obtained from without the base of the levee, and the earth tamped in by horses or mules, ridden rapidly back and forward constantly while the earth is being put in, or by tamping mauls, at least one horse to every ten wheelbarrows, or one tamping maul to six wheelbarrows. This filling and tamping is kept one-quarter mile in advance of the embankment. In case of repair of old levees, all stumps, logs and trees, where they are known to exist, must be dug out and the muck ditch cut near the outside base of the old levee, if considered necessary by the engineer. The surface of all old levees must be well broken. Where the chief constituent of the levee is sand, or other other porous material, the engineer may require a wall of buckshot or clay, 5 ft. thick, to be continued up from the muck ditch to the top of the levee, the earth being tamped in by horses in the same manner as the muck ditch, as the levee is built up on each side of it, the object being to obtain a stratum through the levee, impervious to "sipe water." If the chief constituent of the levee is stiff buckshot or clay, the engineer may require a wall of sand 8 ft. thick, to be continued up from the surface of the muck-ditch to high water mark, as the levee is built up on each side of it, the object in this case being to obtain a perpendicular stratum through the levee impervious to crawfish.

When the ground is prepared, the embankment will be commenced, the slopes being commenced full out to the side stakes and carried regularly up. The embankment must be built one-fifth higher than the grade height marked on the stakes, to allow for shrinkage or settling.

Material is to be obtained from places designated by the engineer, and is not to be taken on the inside of the levee except upon the engineer's orders. At intervals of 100 ft. bermes must be left across the borrow pits

to prevent the flow of a current along the levee. All earth for embankment must be entirely divested of roots, trash and other perishable matter before being put in place.

Where considered necessary the engineer may require a double course of sheet piling, breaking joints to be driven at the center or either side of the levee 5 ft. below the surface of the ground, and extending up to within 6 ins. of grade. The plant to be of heart red gum, white oak or cypress, and of specified dimensions. All piling is driven in advance of the levee, and the embankment constructed on both sides of the piling simultaneously. A breakwater may be constructed where necessary on the river slope of the levee, of post and plank wall, properly braced and filled in behind with earth. In anticipation of destructive floods during the progress of the work, a protection of timber work may be constructed around the ends of the levee, and a temporary protection levee in front of the work.

SPECIFICATIONS FOR MASONRY.

BRICK FOR BUILDINGS.

There is not even a remote approach to uniformity in the specifications for the brick work of buildings. Ordinarily the specifications for the brick masonry are very brief and incomplete. The following conform closely to ordinary construction. Of course, a higher grade of workmanship can be obtained by more stringent specifications.

The brick in the exterior walls must be of good quality, hard burned; fine, compact and uniform in texture; regular in shape and uniform in size. One-fourth of the brick in the interior walls may be what is known as soft or salmon brick. The brick must be thoroughly wet before being laid. The joints of the exterior walls shall be from $\frac{1}{4}$ to $\frac{5}{8}$ inch thick. The joints of interior division walls may be from $\frac{3}{8}$ to $\frac{1}{2}$ inch thick. The mortar shall be composed of 1 part of fresh, well-slaked lime and $2\frac{1}{2}$ to 3 parts of clean, sharp sand. The lime paste and the sand shall be thoroughly mixed before being used. The joints shall be well filled with the above mortar; no grout shall be used in the work. The bond must consist of five courses of stretchers to one of headers, and shall be so arranged as to thoroughly bind the exterior and interior portions of the wall to each other.

The contractor must furnish, set up and take away his own scaffolding; he must build in such strips, plugs, blocks, scantling, etc., as are required for securing the wood work; and must also assist in placing all

iron work, as beams, stairways, anchors, bed plates, etc., connected with the brick work.

BRICK FOR ARCHES.

The specifications for the brick arch masonry on the Atchison, Topeka and Santa Fé Railroad are as follows:

"The bricks must be of the best quality of smooth, hard burnt, paving bricks, well tempered and molded, of the usual size, compact, well shaped, free from lime, cracks and other imperfections, and must stand a pressure of 4,000 pounds per square inch without crushing. No bats will be allowed in the work except for making necessary closures. All bricks will be culled on the ground after delivery, and selected in strick accordance with these specifications.

"The mortar must be made of 1 measure of good hydraulic [Rosendale] cement and 2 measure of clean, sharp sand—or such other proportion as way be prescribed by the engineer well mixed together with clean mater, in clean motar-beds constructed of boards, and must be used immediately after being mixed.

"The brick must be laid flush in cement mortar, and must be thoroughly wet when laid. All joints and beds must be thoroughly filled with mortar so as to leave no empty spaces whatever in the masonry of the walls and arches, which must be solid throughout. The thickness of mortar-joints must be as follows: In the walls and in the arch between bricks of the same ring, not less than three-eighths of an inch ($\frac{3}{8}''$) nor more than one-half inch ($\frac{1}{2}''$). In the arch between rings, not less than one-half inch ($\frac{1}{2}''$) nor more than five-eighths of an inch ($\frac{5}{8}''$). Each brick is to be driven into place by blows of a mallet. The bricks must be laid in the walls with the ordinary English bond, five stretcher courses to one header course. They must be laid in the arch in concentric rings, each longitudinal line of bricks breaking joints with the adjoining lines in the same ring and in the ring under it. No headers to be used in the arch."

RUBBLE MASONRY.

The following requirements, if properly complied with, will secure what is generally known among railroad engineers as superior rubble:

Rubble masonry shall consist of coursed rubble of good quality laid in cement mortar. No stone shall be less than six inches (6″) in thickness, unless otherwise directed by the engineer. No stone shall measure less than twelve inches (12″) in its least horizontal dimension, or less than its thickness. At least one-fourth of the stone in the face shall be headers, evenly distributed throughout the wall. The stones shall be roughly

squared on joints, beds and faces, laid so as to break joints and in full mortar beds. All vertical spaces shall be flushed with good cement mortar and then be packed full with spalls. No spalls will be allowed in the beds. Selected stones shall be used at all angles, and shall be neatly pitched to true lines and laid on hammer-dressed beds; draft lines may be required at the more prominent angles.

The top of parapet walls, piers and abutments shall be capped with stones extending entirely across the wall, and having a front and end projection of not less than four inches (4″). Coping stones shall be neatly squared, and laid with joints of less than one-half inch (½″). The steps of wing-walls shall be capped with stone covering the entire step, and extending at least six inches (6″) into the wall. Coping and step stones shall be roughly hammer-dressed on top, their outer faces pitched to true lines, and be of such thickness (not less than six inches) and have such projections as the engineer may direct.

"The specifications for rubble masonry will apply to rubble masonry laid dry, except as to the use of the mortar."

SQUARED-STONE MASONRY.—Squared-stone masonry is employed for the piers and abutments of the lighter bridges, for arches of 10-foot span and under, for box-culverts, for basement walls, etc. The specifications are usually about as follows:

The face stones shall have quarry faces with edges pitched to a straight line. Each stone shall be dressed to a uniform thickness, with beds throughout. No stone shall be less than eight inches (8″) thick, nor measure in its smallest horizontal dimension less than 12 inches (12″), nor less than its thickness. Joints on the face shall be broken at least eight inches (8″). The bed-joints and also the vertical joints for eight inches (8″) back from the face shall be dressed to one inch (1″). The masonry need not be laid up in regular courses, but shall be well bonded, having at least one header, three feet (3′) long, to every three stretchers.

The stone shall be laid in full cement mortar beds, and the joints shall be packed full.

The backing shall consist of stone not less than six inches (6″) thick. At least one-half of the stones in the backing shall measure two (2) cubic feet. The backing shall be laid in full mortar beds, and the vertical joints shall also be filled with mortar. The spaces between the large stones shall be filled with spalls set in mortar.

The coping shall be formed of large flat stones of such thickness as the engineer may direct, but in no case to be less than eight inches (8″). The

upper surface of the coping shall be bush-hammered, and the joints and beds shall be dressed to one half an inch (½″) throughout. Each stone must extend entirely across the wall when the wall is not more that four feet 4′) thick.

ASHLAR MASONRY.

The specifications for ashlar, or "first-class masonry," as employed on railroads, are about as follows:

First-class masonry shall consist of quarry-faced ashlar, laid in regular horizontal courses, having parallel beds and vertical joints of not less than ten inches (10″) and not more than 30 inches (30″) in thickness, decreasing in thickness regularly from the bottom to the top of the wall.

Stretchers shall not be less than two and one-half feet (2½′) nor more than six feet (6′) in length; and not less than one and one-half feet (1½′) in width, nor less in width than one and one-fourth (1¼) times their depth. Headers must not be less than three and one-half feet (3½′) in length unless the thinness of the wall necessitates it, nor more than four and one-half feet (4½′); and not less than one and one-half feet (1½′) in width, nor less in width than they are in depth of course. The beds and sides of the stone shall be cut before being placed on the work, so as to form joints not less than one-quarter inch (¼″) and not exceeding five-eighths of an inch (⅝″) in width. Every stone must be laid on its natural bed, and all stones must have their beds well dressed, parallel, and true to the proper line, and made always as large as the stone will admit. The vertical joints of the face must not be less than eight inches (8″) in from the face, and as much more as the stone will admit. All corners and batter lines must be built with a neat chisel-draft one and one-half inches (1½″) on each corner. The projections of the rock-face must not exceed four inches (4″) beyond the draft-lines of the masonry; in tunnel side walls this projection must not exceed two inches (2″). The masonry shall consist of headers and stretchers alternating; at least one-fourth of the wall shall consist of headers extending entirely through the wall. Every header shall be immediately over a stretcher of the underlying course. The stones of each course shall be so arranged as to form a proper bond with the stones of the underlying course. A bond of less than one foot (1′) will in no case be allowed.

The masonry shall be laid with cement mortar consisting of 1 volume of cement of the Rosendale type and 2 volumes of sand. Each stone shall be cleaned and dampened before being set. No hammering on the wall will

be allowed after the course is set; but if any inequalities occur, they must be carefully pointed off.

The backing shall be of good-sized, well-shaped stones, laid so as to break joints and thoroughly bond the work in all directions and leave no spaces between them over six inches (6′) wide, which spaces shall be filled with small stones and spalls set in cement mortar.

All foundation courses must be laid with selected, large, flat stones not less than twelve inches (12″) in thickness, nor of less superficial surface than fifteen (15) square feet.

The coping shall be formed of large flat stones, which shall extend entirely across the wall when the same is not more than six feet (6′) wide. The steps of wing walls shall be capped with stone covering the entire step and extending under the step next above at least twelve inches (12″). Coping and step stones shall be at least twelve inches (12″) thick, and have such projections as the engineer may direct (usually 3 to 6 inches). The tops and faces of copings and step stones shall be bush-hammered and their joints and beds cut to one quarter inch (¼″) throughout.

CHAPTER VII.

Culverts and Bridges.

STANDARD TIMBER BOX CULVERTS.

Reprinted from the Railroad Gazette.

There is a strong feeling among engineers, which finds expression in the construction of nearly all lines on which timber is used at all, that the use of timber box culverts is bad practice; that where the fill is not over 6 or 8 feet high—or sometimes even 10 feet high—open timber culverts should be used instead, and where the fill is too great for such open culverts, pile or timber trestles should be used, or else masonry. The practice of the Chicago, Milwaukee & St. Paul is different from this, on all the thousands of miles which it has built or is building, where stone cannot be obtained at all, or only with much difficulty and cost. In such cases, the rule on that line, even in timber work, is never to use an open culvert when timber can be used instead. In this it is not alone, but we believe it is fairly entitled to the credit of having set the fashion, which is not yet a very general fashion.

It is defended by the following argument: That though it is true that the wood decays, and though it is true that there is somewhat less certainty of knowing of dangerous decay in advance, yet it is not true that decay is more rapid than with open structures, nor that they are as likely to give way when they are decayed, nor that the consequences are likely to be so serious if they do give way. In the meantime the average condition of a poorly ballasted or wholly unballasted track is very much better than with open structures.

Therefore, the practice on that line is to use timber box culverts wherever possible, to have them inspected periodically and carefully, and whenever their condition demands it and convenience serves, to renew them, not with stone but, as a rule, with iron pipes. It is not found in practice, however, that even a considerable amount of decay endangers caving in of the bank greatly, especially when the bank is of some considerable height. After the bank has once become solid, on the contrary, which of course is long before the timber begins to decay seriously, it is

LONGITUDINAL SECTION

NOTE—The two Timber Culverts with opening of 3'4" and 4'8" are to be used only when Bank is too low to admit of the Square Form, with not less than 6 inches of earth on top of Covering.

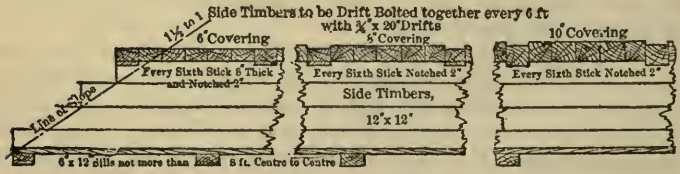
TWO-TIMBER CULVERTS.

LONGITUDINAL SECTION

THREE-TIMBER CULVERTS.

LONGITUDINAL SECTION

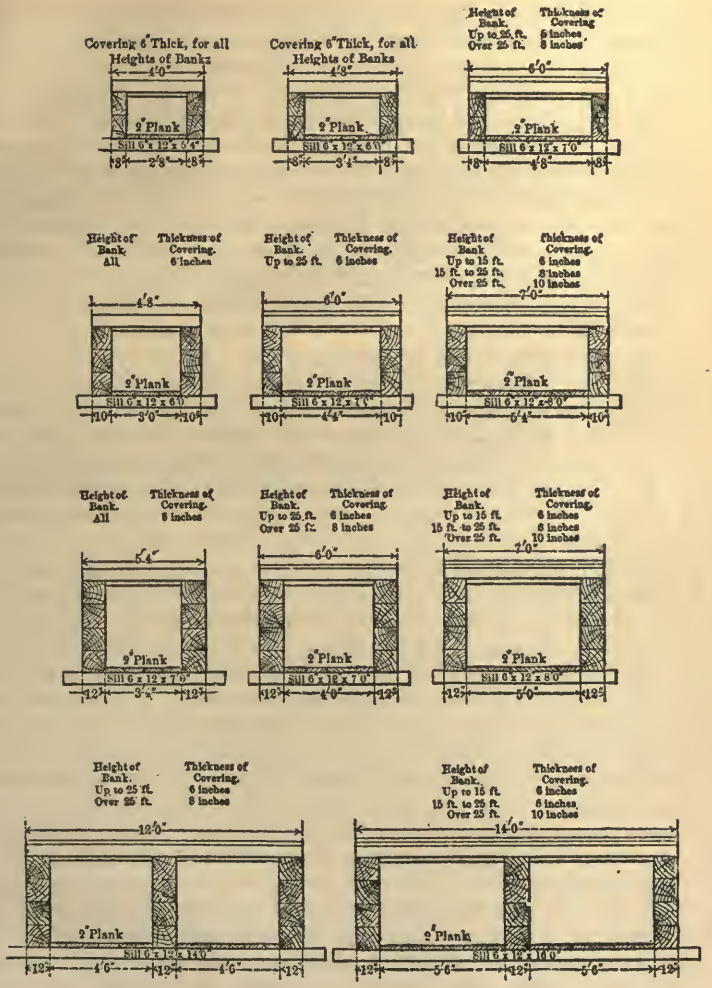
FOUR-TIMBER CULVERTS.



LONGITUDINAL SECTION

FOUR TIMBER DOUBLE CULVERTS.

Standard Timber Box Culverts.—Chicago, Milwaukee & St. Paul Ry.



Standard Timber Box Culverts.—Chicago, Milwaukee & St. Paul Ry.

found that they very seldom cave in, and that in putting in the iron pipe the timber may be almost completely cut away at top, bottom and sides for the insertion of circular pipes without danger; a safe indication for the workmen being that wherever the timber is punky and rotten there can be no immediate danger in removing it altogether, and after the expiration of very much less than 15 to 20 years, which is no unusual time for these culverts to remain in service, all the interior of the wood at least where it is exposed to the air, is pretty sure to be punky and rotten, its chief and all-sufficient function seeming to be to sustain the pressure of earth during the process of solidification only, and thereafter chiefly to protect the interior surface of the earth fill from the influence of the atmosphere, which alone suffices to restrain all considerable tendency to cave.

It follows that the size of the iron pipes which are ordinarily used for renewal, when it is not clearly safe to use a smaller pipe, will be given by determining with a pair of dividers the largest circle which can be drawn within the exterior limits of the culvert walls without cutting away more than half or two-thirds of the thickness of the wood at top or sides at any point, the greatest liberties being taken of course with bottom timbers. In doing this, the first section of the pipes is entered at one end and drawn clear through to the other end by appropriate tackle, the workmen clearing away in advance of it. After the first pipe has been drawn through and placed in position, the following pipes are drawn up to it in succession, one after another, very speedily, and the whole work is complete. A masonry end may or may not be added. The pipes used range from 24 to 60 in. in diameter, and are cast at the company's foundry of any scrap which comes convenient. They are provided with a simple bell mouth large enough merely to hold the pipes in line with each other without any attempt at calking.

The sizes of pipe used, of course, depend largely on what has proved to be the requirements of the water way. When the culvert has been in use some years the presumption is fair that no larger water way than before is necessary, and this, or even more, is readily obtained by pipes in the manner described.

Whether or not this manner of using and renewing wood is good and safe practice is simply a matter of experience. Experience in almost all kinds of soil appears to indicate that it is, a notable advantage being that in the rare cases where culverts cave in they do not, as a rule, produce a dangerous disturbance of the surface, whereas if an open culvert or tres-

tle has been carelessly allowed to become too weak, an accident is almost certain, while it is almost impossible to make a new track with many open structures in it ride even fairly well.

There is perhaps no detail of American practice in which foreign critics, accustomed to new lines made thoroughly solid and complete before they are allowed to be opened, are more apt to comment unfavorably than on the practice of opening first with temporary works, and completing with permanent works afterwards, which may be called the standard American practice. Yet there is much to be said for it.

There are three other considerations of great weight:

First.—The exact requirements of the locality become better known, and costly and dangerous mistakes may be more fully avoided.

Second.—The work can be prosecuted in a more leisurely manner and at more appropriate seasons, and thus greater durability insured.

Third.—The work can be prosecuted more cheaply, there being the advantage of locomotive power for delivering stone, cement and iron work and for making fills by trains; often at but a fraction of the cost of executing the permanent work in advance of these facilities.

As for safety, there is no question but that wooden structures, properly designed and properly watched and renewed, are entirely safe, and the thing to be protested against, therefore, is lack of care and skill in using them and not the things themselves. The difference in the cost of a good and of a bad wooden structure is not so good that there is ever any excuse for the latter, though it must be admitted that they are far from unknown.

For these reasons there is no apology demanded for the reasonable and cautious use of the practice of "opening roads first and building them afterwards," as it has been called, even when, as on the Chicago, Milwaukee & St. Paul and thousands of miles of other road in the West, the use of stone structures for opening the road is wholly out of the question.

MAXIMUM SPANS OF STONE BOX CULVERTS.

BY EMILE LOW, C. E.

The table given below shows the maximum span or horizontal inside opening of box culverts, having covering stones of good sandstone, varying in thickness from six (6) to eighteen (18) inches, and being under embankments of from four (4) to one hundred (100) feet in height.

The table has been calculated for an earth embankment, the weight of a cubic foot of earth having been taken at eighty (80) pounds.

Should the embankment be made of heavier material, such as rock, a reduction of the span must then be made.

The ultimate tensile strength of the stone has been taken at eight hundred and sixty four (864) pounds per square inch, but one-tenth of that, or eighty-six and four-tenths (86 4-10) pounds per square inch, has been used in the calculation of the tables.

The formula used is as follows:

$$l = \frac{1.2 \times c}{\sqrt{H}}$$

in which

l = clear span in feet.

c = depth of covering stone in inches.

H = height of earth embankment over covering stone in feet.

Height of embankment.	Span of Box Culverts with covering stone, the following depth in inches.				
	6″	9″	12″	15″	18″
4	3.60	5.40	7.20	9.00	10.80
9	2.40	3.60	4.80	6 00	7.20
16	1.80	2.70	3.60	4.50	5.40
25	1.44	2.16	2.88	3.60	4.32
36	....	1.80	2.40	3.00	3.60
49	....	....	2.06	2.57	3.09
64	....	....	1.80	2.25	2.70
81	....	....	....	2.00	2.40
100	....	....	....	....	2.16

I also append a table showing the weight of the superincumbent embankment (taken at 80 pounds per cubic foot), for the length of one (1) foot of the same in the direction of the axis of the culvert and in width equal to the spans as given above for the different heights of embankments.

Height of embankment.	Weight of Embankment in pounds per lineal foot of Culvert and for widths as per table above.				
4	1152	1728	2304	2880	3456
9	1728	2592	3456	4320	5184
16	2304	3456	4608	5760	6912
25	2880	4320	5760	7200	8640
36	....	5184	6912	8640	10368
49	....	....	8064	10080	12096
64	....	. ..	9216	11520	13324
81	....	....	....	12960	15552
100	....	....	....	....	17280

SPECIFICATIONS FOR STONE BOX CULVERTS.*

All stone box culverts shall have a water way at least $2\frac{1}{2} \times 3$ feet. The side walls shall not be less than two feet (2′) thick, and shall be built of

*Pennsylvania Railroad.

sound, durable stones not less than six inches (6″) thick, laid in cement mortar [usually 1 part Rosendale cement to 2 parts sand]. The walls must be laid in true horizontal courses, but in case the thickness of the course is greater than 12 inches (12″), occasionally two stones may be used to make up the thickness. The walls must be laid so as to be thoroughly bonded, and at least one fourth of the area of each course must be headers going entirely through the wall. The top course must have one-half its area of through stones, and the remainder of this course must consist of stone going at least one-half of the way across the wall from the inside face. The face stone of each course must be dressed to a straight edge, and pitched off to a true line. All of the coping stones of head walls must be throughs, and must have the upper surface hammer-dressed to a straight edge, and the face pitched off to a line with margin draft. Cover stones shall have a thickness of at least twelve inches (12″) for opening of three feet (3′), and at least 14 inches (14″) for opening of four feet (4′); and must be carefully selected, and must be of such length as to have a bearing of at least one foot (1′) on either wall.

The beds and vertical joints of the face stones for a distance of six inches (6″) from the face of the wall shall be so dressed as to require a mortar joint not thicker than three-fourths of an inch (¾″). Joints between the covering stones must be not wider than three-fourths of an inch (¾″), and the bearing surface of cover stones upon side walls must be so dressed as to require not more than a one-inch (1″) mortar joint.

The paving shall consist of flat stones, set on edge, at right angles with the line of the culvert, not less than twelve inches (12″) deep, and shall be laid in cement mortar and grouted.

SPECIFICATIONS FOR STONE ARCH CULVERTS.*

Foundations.—" When the bottom of the pit is common earth, gravel, etc., the foundations of arch culverts will generally consist of a pavement formed of stone, not less than twelve inches (12″) in depth, set edgewise, and secured at the ends by deep curbstones which must be protected from undermining by broken stone placed in such quantity and position as the engineer may direct. When the bottom upon which a culvert is to be built is soft and compressible, and where it will at all times be covered with water, timber well hewn, and from eight (8″) to twelve inches (12″) in thickness, according to the span of the culvert, shall be laid side by side

* Pennsylvania Railroad.

crosswise upon longitudinal sills; and when the position of the culvert is such that a strong current will be forced through during floods, three courses of sheet piling shall be placed across the foundation, one course at each end, and one in the middle,—which shall be sunk from three (3′) to six (6′) below the top of the timber, according as the earth is more or less compact."

First-Class Arch Masonry.—"First-class arch masonry shall be built in accordance with the specifications for first-class masonry *[§225], with the exception of the arch sheeting and the ring stones. The ring stones shall be dressed to such shape as the engineer shall direct. The ring stones and the arch sheeting shall be of stone not less than 10 inches (10″) thick on the intrados, shall be dressed with three-eighths of an inch (⅜″) joints, and shall be of the full depth specified for the thickness of the arch; and the joints shall be at right angles to the surface of the intrados. The face of sheeting stones shall be dressed to make a close centering joint. The ring stones and the sheeting shall break joints not less than one foot (1′).

"The wings shall be neatly stepped with selected stones of the full width of the wing and of not less than ten inches (10″) in thickness, which shall overlap by not less than eighteen inches (18″), or shall be finished with a neatly capped newel at the free end, and a coping course on the wing. The parapets shall be finished with a coping course not less than ten inches (10″) thick and of the full width of the parapet, which shall project six inches (6″)."

Second-Class Arch Masonry.—"Second-class arch masonry is the same as second-class masonry, with the exception of the arch sheeting. The stones of the arch sheeting shall have a good bearing throughout, and shall be well bonded and of the full depth of the thickness of the arch. No stone shall less than four inches (4″) in thickness on the intrados. Ring stones of all arches over eight feet (8′) span shall be dressed according to specifications for first-class arch masonry."

* Baker's Masonry Construction.

HOWE TRUSS BRIDGES.

In ENGINEERING NEWS of April 26, 1890, a double page lithographed inset was published, showing 27 strain sheets and sizes of members for Howe truss bridges from 30 feet to 150 feet span, sent by Chief Engineer A. A. Schenck, of the Oregon Pacific Railway Co., and which we believe to be safe and careful designs, in accordance with the latest and best practice in wooden bridge construction, which for a long time to come will be an important department of American engineering work, although one of continually decreasing relative importance.

One fact we should especially call attention to, that these bridges are designed for a region where very long timber is readily obtained, and is no more expensive than short timbers, so that the sections given for lower chord would be much weaker in proportion to regions where equally long timber was not available. The great difference in the amount of iron required when the rods are upset or not upset, is curiously shown in the table of data herewith reprinted:

TABLE OF DATA.

No. of Span.	Assumed loading per foot.			Total load per foot. lbs.	Estimate of Quantities.			W. Iron. Lbs. Rods upset.
	Trusses lbs.	Floor lbs.	Train lbs.		Timber Ft. B.M.	W. Iron lbs.	C. Iron lbs.	
1	360	500	5,060	5,620	10,165	2,170	,970	
2	360	"	5,060	5,920	6,750	1,930	1,210	
3	400	"	4,600	5,500	13,358	2,960	1,070	
4	400	"	4,600	5,500	9,362	3,280	1,550	
5	450	"	4,200	5,150	19,025	5,610	2,880	
6	450	"	4,200	5,150	12,861	4,710	2,830	
7	540	"	3,860	4,900	22,785	6,790	3,660	
8	540	"	3,860	4,900	20.702	5,900	3,830	
9	600	"	3,640	4,740	29,931	9,260	8.260	8,210
10	600	"	3,640	4,740	27,617	8,420	7,980	7,610
11	620	"	3,600	4,720	35,388	11.660	9,790	10,260
12	620	"	3,600	4,720	32,764	10,190	9,730	9,120
13	720	"	3,560	4.780	42,709	15,170	12,530	13,440
14	720	"	3,560	4,780	41,883	17,880	12,260	15,150
15	720	"	3,560	4,780	40,690	13,220	12,710	11,820
16	800	"	3,500	4,860	48,892	22,580	14,290	18,950
17	800	"	3,500	4,800	46,454	18.040	13,990	16,040
18	880	"	3,400	4,780	54,767	25,820	15,930	22,290
19	880	"	3,400	4,780	50,295	19,400	14,050	16,320
20	940	"	3,300	4,740	62,038	30,890	18,290	26.010
21	940	"	3,300	4,740	59,254	23,080	16,520	19,580
22	1,000	"	3,200	4,700	70,128	37,050	20,830	30,180
23	1,000	"	3,200	4,700	66,779	27,930	20,460	23,560
24	1,050	"	3,150	4,700	78,156	40,820	23,210	33,020
25	1,050	"	3.150	4,700	76,323	32,640	23,260	27,360
26	1,100	"	3,100	4,700	86,632	48,090	27,060	39,140
27	1,100	"	3,100	4,700	86,053	39,630	27,140	33,390

Strains given are for one truss, and in 1,000 pounds.
Sections given are for one truss (rods assumed not upset).
Loads in above table are for two trusses.
Strains are those due to dead load + maximum from moving load.
Assumed live loads are intended to fully equal (in strains produced) those given in diagram below.
Load on a floor beam, 14,000 pounds, on a panel length of chord as a beam; 36,000 pounds on an axle.
Wrought iron in tension, 10,000 pounds (net section at root of thread) per square inch.
Wood (in compression only) 1-6 to 1-8 of breaking load by Smith's formula.
Wood (in tension only) usually 800 pounds to 1,000 pounds, (500 pounds to 800 pounds in shortest span), per square inch; and as packed beam maximum section (net section) 800 to 1,000 pounds.

LATERAL SYSTEMS.

DECK SPANS—A uniform load of 150 pounds per foot (each system), ½ of it at feet of rods.
A moving load of 150 pounds per foot (each system), all of it at feet of rods.
Sway braces at each panel assumed to equalize the strains so that each system is the same (except end rods).
THROUGH SPANS—A uniform load of 150 pounds to 200 pounds per foot (each system). A moving load of 300 pounds per foot (lower system).
Iron 13,000 to 15,000 pounds per square inch net. Timber 1-4 to 1-5 breaking load.

The spans included in the diagrams are :

30 ft. half-through and deck.	100 ft. through, and deck.
40 " " " "	110 " " "
50 " " " "	120 " " "
60 " " " "	136 " " "
70 " " " "	140 " " "
80 " " " "	150 " " "
90 " through, half-through and deck.	

This includes in all 27 different trusses, covering the entire range usually required for wooden trusses, spans exceeding 150 feet being rarely built of wood.

In a letter transmitting these strain sheets, Mr. W. A. DOANE, M. Am. Soc. C. E., gives the following further details:

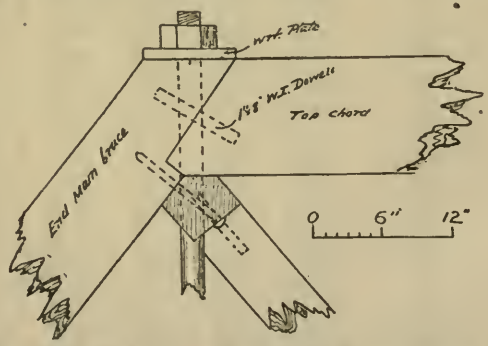


Fig. 1. Top Chord End Joints for Howe Truss Spans up to 90 ft.

"Howe truss bridges, not yet having had their day—at least in the South and West—I send you a set of strain sheets from 30 feet to 150 feet spans, designed for heavy traffic. They require little explanation beyond that given by the attached notes and table of data.

It is intended to use upset rods for all spans above 60 or 70 feet, although diameters given are those required to give the necessary area at root of thread. The table of data gives approximate weights in each case. As will be seen, from 1,000 to 9,000 pounds of iron per span are saved by upsetting the ends of rods.

It is believed that some details of construction have been improved in these designs.

"Fig. 1 (enlarged scale) shows the general style of joints at junction of top chord with end mains for all through spans up to 90 feet.

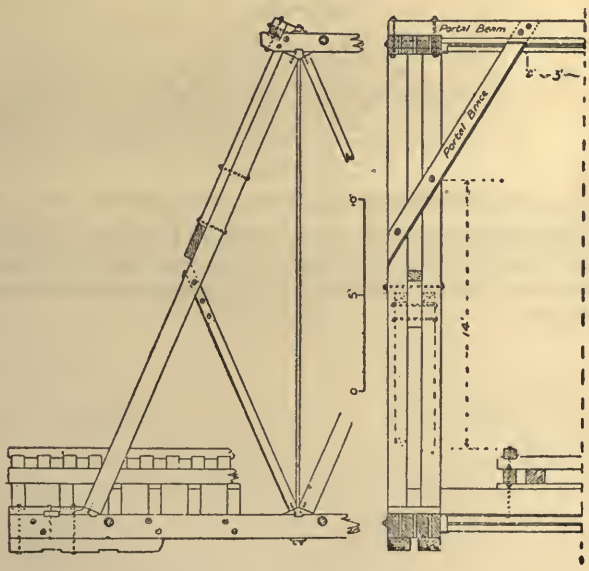


Fig. 3. Portal Bracing for Howe Truss Through Spans of 90 ft. and over.

"Fig. 3 shows general style of portal bracing, etc., for through spans over 90 feet, these having a system of top lateral bracing. In no case are vertical end posts used to meet a useless prolongation of top chord in through spans.

"For spans of 100 feet and over, the usual style of cast brace blocks is followed, having tubes slightly let in to chord timbers and long enough to reach the opposite face of chord and receive the strain transmitted from the rods through the plates. These latter are in all cases made unusually wide, however.

"In spans less than 100 feet the tubes are dispensed with, and a block of the style shown in Fig. 2 is used, having a full bearing on the chord as well as for the braces, while the radial longitudinal ribs greatly increase the strength. The open ends are not objectionable."

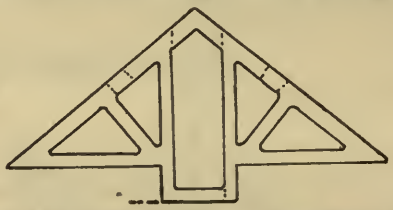


Fig. 2. Cast Brace-Block for Howe Truss Spans under 100 ft.

It was not practicable to reproduce the sheet of diagrams for this book. The reader who wishes to post himself on the best practice in Howe truss construction can consult the number of the journal in which the diagrams are published.

COST OF LABOR IN FRAMING AND ERECTING A WOODEN HOWE TRUSS BRIDGE.

We have had sent to us a very full and careful set of notes, detailing the actual cost for labor of framing and erecting five spans of 150 ft. each, of a wooden arched Howe truss bridge, built by one of the best known firms in the country. We give an abstract of these for the benefit of any whom it may concern. The general dimensions of the bridge were as follows:

Number of spans	5
Number of trusses to each span	2
Number of arches to each truss	2
Length of truss, c to c., of end angle-blocks	149 ft. 4 in.
Length of panel over pier	2 ft. 8 in.
Number of panels in each truss	14
Length of each panel	10 ft. 8 in.
Projection of chords beyond centre of end angle-block	2 ft.
Height of truss between chords	20 ft.
Depth of lower chord	14 in.
Depth of upper chord	12 in.
Width of chord	2 ft. 3 in.
Depth of arches (3 pieces, 8 in. × 9 in., 1 in. spaces)	2 ft. 5 in.
Width of arches	8 in.
Width of bridge in clear between trusses	19 ft. 4 in.
Width of bridge in clear between arches	18 ft.
Radius of upper line of arch	108 ft. 4 in.
Length of bridge centres of end angle-blocks	757 ft. 4 in.

The wages paid were as follows: Foreman, $3.60 per day; carpenters, $2.75; helpers, $2.25, and laborers, $1.85. Work was commenced in October, 1873, and continued without interruption thereafter until July, 1874, when the bridge was completed.

The cost of the work may be itemized as follows:

Framing arches, cost	$495.31	
Painting arches, "	29.70	
Total	$525.01 or 66c. per lin. ft. bridge.	
Framing trusses, cost	$2.002.62 or $2.64 " " "	
Painting daps, etc., cost	105.70 or 14c. " " "	

Framing the false works, making "balance beams" for raising, making a flat and preparing generally for the erection of bridges cost as follows:

Framing false works	$57.96
Preparing for raising	173.98
Painting iron	42.75
Total	$274.69

Time consumed in framing false works, 3½ days' work of 7 men.

The cost of raising—for one foreman and 19 men, working 79 days, in-

cluding a bill of $220.61 for watchman, horse, blacksmithing and expenses—was $2,989.45; reduced to cost per lin. ft. of bridge this amounted to:

False works	$57.96 or	$0.08	per lin. ft. bridge.
Painting iron	103.65 or	0.14	" " "
Raising bridge	2,989.45 or	3.94	" " "

Or to summarize under the following general heads, the

Framing cost	$2,603.63 or	$3.44	per lin. ft. of bridge.
Raising cost	3,151.06 or	4.16	" " "
Total cost	$5,754.69 "	$7.60	" " "

The cost of lumber and iron is, of course, not included in the above account, which simply covers the labor.—*Engineering News*, March 24, 1883.

HOWE TRUSSES ON THE CANADIAN PACIFIC RAILWAY.

The Howe trusses nearly all have the following floor: Guard rails, 8 in. × 8 in., sized to 6½ in. at ties, placed 10 ft. 6 in. apart in the clear, bolted through the tie and outside stringer by ¾-in. bolts (¾ in. × 3½ in. cast washers); ties 8 in. × 8 in., 12 ft. long, spaced 16 in. centres; every 5 ft. 4 in., or every fourth tie guard rail, tie and stringer bolted. The ties are sized to 7½ in. at the stringers on some bridges. Six lines of stringers, all 8 in. × 10 in., two under each rail, breaking joints and packed 3 in. apart. Packing bolts ¾ in. (about 5 ft. apart). The other four stringers are under the guard rails. In each panel there are four ¾-in. bolts through one of the stringers and floor beam. The floor beams vary from 6 in. × 15 in. to 9 in. × 15 in.; 4 to 5 per panel, bolted through the chord by ¾-in. bolts.

All through bridges are 15 ft. wide in clear, and, where the top lateral bracing is used, are about 21 ft. from top of rail to bottom of braces.

The dead load is generally 10% greater than given by TRAUTWINE for the trusses, and 400 to 650 lbs. per ft. for the floor.

Iron in tension is strained not to exceed 10,000 lbs. per sq. in. of net section; wood in tension, 800 to 900 lbs. Wood in compression, $\frac{1}{6}$ to $\frac{1}{8}$ breaking load, by S. C. Smith's formula. Wood as a beam, etc., 800 to 900 lbs. per sq. in. on extreme fibres; keys, post blocks, packing, clamps, brace-blocks, are all of white oak.

The 147-ft. spans have iron clamps and lower chord post blocks. All spans of 50 ft. and over have iron brace and lateral blocks, except the 50-ft. through span. There is the same number of panels of lateral bracing as of vertical in all trusses. Much of the counter bracing is in excess. In the skeleton diagrams the height is centre to centre of chords, and the

length, from face to face of end post. All main rods have upset ends. Hexagonal nuts are used, with 8 to 10 ins. of thread at each end. With plates no washers are used. The lateral rods have square nuts 5 ins. of threads, all upset.

FORMULAS FOR WEIGHTS OF BRIDGES.

The following formulas for computing the approximate weights of bridges are taken from Merriman's Text Book on Roofs and Bridges :

For a highway bridge let l be the span in feet, b the width in feet (including sidewalks, if any) and w the weight in pounds per linear foot, then,

$$w = 140 + 12\,b + 0.2\,b\,l - 0.4\,l.$$

For a railroad bridge the weight per linear foot can be roughly found from the following formulas for spans less than 300 feet in length :

For single track $w = 560 + 5.6\,l$.

For double track $w = 1{,}070 + 10.7\,l$.

Wooden bridges weigh about the same as iron of equal strength.

CHAPTER VIII.

Construction Details.

CENTRES FOR ARCHES.

There is nothing connected with the construction of stone or brick arches which requires more careful attention on the part of the builders than the centres—it matters not what the shape or span, or for what particular purpose the arch be intended. Aside from the choice of material and the care with which other parts of the construction are performed, the settlement and ultimate stability of the arch decidedly depends on the framing, setting and striking of the centres. The yielding of a brace of improper dimensions, or a slight change in the shape of the frame caused by an ill-seasoned timber, may result in so changing the shape of the intrados as to endanger the safety of the arch. It must be the object of the engineer, in all large-spanned arches, to determine by what combination of beams and by what system of bracing the greatest strength and stiffness may be secured, combined with lightness and economy of materials.

When in position the centres are placed about 5 to 7 feet centre to centre and are known as ribs. Pieces of board or plank, called laggins, are placed horizontally upon them, on which rest the voussoirs until the keystone is inserted, when the arch becomes self-supporting. The framework of the centre consists of short beams which are cut on the outer edge to form parts of a curve, and when put in place they unite to form the same curve as the intrados of the arch. These are held in place by horizontal tie-beams, struts, ties and braces, the arrangement, number and dimensions of which will depend upon the shape and span of the arch as well as number and position of the points of support.

Experience shows that whatever be the shape or span, the arrangement of the ribs in the form of a polygon is the best in every case. This shape is acquired by the arrangement of the short beams or back-pieces, which usually consist of two or more pieces of plank firmly nailed together and abutting end to end, forming a joint in the direction of the radius of curvature of the arch. It is obvious that the strains to which

the centres are subjected arise slowly from the pressure upon the back-pieces and laggins. Therefore the strains depend upon the span and curve of the arch and the thickness and weight of the voussoirs which rest upon the centring. All the voussoirs from one springing line to the other do not, however, press upon the frames. This depends very greatly upon the degree of curvature of the arch. In a full-centred arch the voussoirs exert no pressure upon the frames for a considerable distance above each springing line, but when the point is reached where the stones begin to exert a pressure upon the frames, such pressure increases very rapidly as we approach the crown and reaches its maximum intensity just before the key-stone course is driven into place. These voussoirs which lie near the springing-plane and exert no pressure upon the laggins and back-pieces are all situated within the angle of repose—in other words, the voussoirs do not begin to press upon the centring until we meet one whose lower joint makes so great an angle with the horizontal as to cause it to slide under the force of gravity.

For ordinary cut stone, the angle of repose of a full-centred arch has been found by experiment to be about 30°; but if the stone be laid in full mortar it will be very nearly 45°. The number of stones, then, that will load the centre-frame, taking the angle of repose at 30°, will depend entirely upon the form of the curve given to the intrados. For example, in a full centre, an oval and a flat segmental arch, having the same number of voussoirs, it is plain that the number of stones which do not press upon the laggins will be greatest in the first-mentioned arch, less in the second and still less in the third. Those stones which do press upon the laggins do not do so with their entire weight, owing to the friction of the surfaces of contact which the weight of the stone is compelled to overcome.

According to Rankine the total weight of each stone which presses upon the laggins is to the weight with which they actually load the frame as an arc of 60° is to twice its sine less the same angle, or the relation may be thus expressed:

Let W = total weight of voussoirs which rest on centring
and w = weight with which they load centring.

Then we have $W : w :: \text{arc } 60° : 2 \sin 60° - \text{arc } 60°$,

$$\text{or } w = \frac{W(2 \sin 60° - \text{arc } 60°)}{\text{arc } 66°}.$$

Now let the radius be divided into any number of equal parts, say r = 15000. The circumference will then contain 94248 and the arc of 60° — 15708. The sine of the arc of 60° will be $r \times \frac{1}{2}\sqrt{3} = r \times .8660 \doteq 12990$.

Substituting these values in the above equation we have

$$W : w : : 15708 : 2 \times 12990 - 15708,$$

which gives a ratio of 3 to 2, nearly.

We therefore conclude that about $\frac{2}{3}$ of the weight of those stones which lie without the angle of repose actually press upon the laggins; and taking into account the 60° contained in the angles of repose on both sides, we find that about $\frac{2}{3} \times \frac{2}{3} = \frac{4}{9}$ of the gross weight of the arch expresses the load of the centres. The case is entirely similar with arches which are not full centred. In order, then, to determine the gross weight of that portion of the arch which presses on the back pieces and laggins and causes stresses in the framework of the centres, it is only necessary to know the number of voussoirs, their volume and weight per cubic foot. If the centres are subject to other stresses besides those caused by the voussoirs, as is sometimes the case in tunneling where the timbering is removed before the keystone course is driven, such additional stresses must be provided for.

The direction and intensity of strains caused by the voussoirs may easily be found by resorting to parallelogram of forces.

For example, the weight of any arch stone or any number of arch stones, which acts vertically downward through its centre of gravity, may be resolved into two components, one of which will be normal to the lower radial joint of the arch and will represent in magnitude and direction the weight which is *not* supported by the rib, but which is resisted by the lower part of the arch and finally by the abutment, and the other in the direction of the radius of curvature of the intrados representing in magnitude and direction the weight which must be resisted by the centring.

The strains then take the direction of the radius of curvature of the intrados. Now, to find the position of the beams which are to withstand these strains, also their number and dimensions, is next required. It is evident that a horizontal beam loaded at its middle will offer its least resistance to the load. If, now, one end of the beam be raised so that the direction of strain is oblique to the fibers of the beam, the resistance in the latter case will be to that in the former as the cosine of the angle made by the direction of the strain and the fibres of wood is to sine 90° or 1. It should follow that when the angle between the beam and strain is zero the resistance becomes infinite, and if it were not for the compressibility and certain other physical causes such would be the case. However this may be, the beam is certain to be strongest in the direction of its fibres, hence the greatest stiffness and strength will be gained when the principal

pieces are placed in the direction of the strains; that is, in the direction of the radius of curvature of the arch. The practical application of this arrangement of beams is, however, restricted to small arches, because when timbers are 30 or 40 feet long it fails utterly. For while a beam of 10 feet long will offer great resistance to compression in the direction of its fibers, a beam 40 feet long would be sure to bend and require bracing. In order, therefore, to arrive at an arrangement which will adapt itself to large arches, if we resolve the radial stresses of two symmetrical portions of the arch, with respect to a vertical plane through the center of the arch and in the direction of its length, into horizontal and vertical components, these components will represent the direction of three beams, one horizontal spanning the arch and supported at each end by a vertical beam. According to Drinker on Tunneling, this horizontal beam is placed about 45° up the arch, in practice. The voussoirs above this tie beam are then supported by another horizontal tie beam upheld by small vertical beams abutting on the lower tie.

Now, then, knowing the pressure exerted on the centre, and being able to calculate the pressure upon any segment thereof ; also, having decided upon the number and arrangement of members, the strains may be found either analytically or by the graphical method. After determining the stresses the members may be proportioned with Gordon's formula, using a factor of safety of 4 to 6.

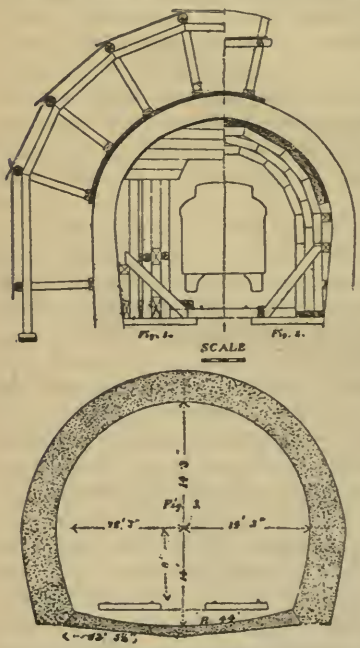
The centring should be slightly higher in the middle than the intended height of the finished arch, in order to allow for deflection. By experience the amount of deflection is found to be $\frac{1}{400}$ of the radius of curvature. The centring must, therefore, be made $\frac{1}{400}$ of r higher at the crown than the finished arch is intended. When the keystone course has been driven the striking of the centres must be deferred for some days, or even weeks, in order to give the cement time to settle properly. It has been found by experience, however, that it is well to very slightly withdraw the centring soon after the arch is finished, in order to allow for the deflection before the cement is perfectly settled. A very satisfactory method, with this object in view, is to have the centring supported by means of hollow cylindrical columns filled with sand. The weight rests on the sand by means of pistons, which project into the top of the column, while the pillars rest on solid foundations. There is a small opening near the bottom of each pillar, and when the arch is ready to be decentred a small portion of the sand is let out, thus allowing the arch to deflect very gradually.

N. J. WITMER.

REPAIRS TO THE ARCH OF THE MUSCONETCONG TUNNEL.

[Published by permission of the Lehigh Valley Railroad Co.]

The Musconetcong Tunnel is situated in New Jersey, on the line of the Lehigh Valley Railroad, about twelve miles from Easton. In the autumn of 1871 and the winter of 1872 the location was decided upon. The road was at that time divided into four divisions, Mr. Robert H. Sayre, Chief Engineer of the Lehigh Valley Railroad, being also Chief Engineer of the Easton & Amboy Division, in which the tunnel is located. Mr. Calvin E. Brodhead was Principal Assistant; Mr. John L. Wilson, Division Engineer; Mr. Henry S. Drinker, Resident Engineer, and Mr. Charles McFadden, of Philadelphia, Contractor.



The tunnel is through a spur of the Musconetcong Mountains (that range which extends over Northern New Jersey and into Southern New York), and is 5,136 feet long. At the west end it passes through 770 feet of soft ground, 702 feet of which is arched, the remainder being taken out in open cut, 450 feet of limestone, 263 feet of loose rock and 3,731 feet of syenite, declared by competent judges to be harder and tougher than any rock encountered along the line of the Hoosac Tunnel.

In April, 1872, ground was broken on the west cut, work starting soon after on the east end, and in December, 1874, the headings met. It was decided to commence by a slope down to the level of the proposed headings, which were then to be run in both directions. This was on the west end in the earthy portion of the tunnel, the east end being run full size. The slope having been dug, work was commenced on the headings, but the ground was very heavy, requiring careful timbering. Springs of

water were constantly encountered, and finally one spring struck with which two large pumps were unable to cope; the water gained rapidly, the timbering was undermined and the entire work ruined. After this the slope was abandoned; a shaft was sunk to the west and headings run each way until the water was struck, when it was carried out through the west heading. This portion of the tunnel was the most troublesome, and has kept up its reputation in this respect ever since.

That portion of the tunnel through the earth, and also where the loose rock was encountered at the junction of the limestone and the syenite, was arched, there being 50 feet of stone arching at the west end, the remainder of brick. The backing was dry rubble.

For a number of years the brick arch gave good satisfaction, but finally it began to fail. Longitudinal cracks were opened, and at last it grew so bad that the bricks would fall out under the jarring of the passing trains. The cause of this failure is not known, the mortar used not having been injured by the water, as afterwards proved. It is probable that the rubble backing was not packed tight enough, thus allowing a pressure from above to be transmitted directly to that portion of the arch below, instead of being distributed uniformly over the entire arch.

Several remedies were suggested and plans made, but first it became necessary to timber the failing part, or there was danger of the entire arch collapsing. The great problem was to put in solid timbering and still not interfere with the trains. The double track was changed to a single one raised on sills and timbering put in as shown in Figs. 1 and 2. The first kind (Fig. 1) was used for 255 feet at the west end, 215 feet of this having knees, and 410 feet of the second kind (Fig. 2). The tunnel starts at station 676+65, and at station 678+20 double timbering was used on account of the character of the arch at that point. The bents are five feet apart, centre to centre, of pine and hemlock, the sills are 8″ × 12″, the posts 12″ × 12″, and the corbels 12″ × 12″. To withstand any lateral pressure the bents are connected by short struts, 12″ × 12″ hemlock. It will be seen by an inspection of the figures that this timbering is put up in the most substantial manner. The second kind is considered the best, as in it no distortion can take place unless the bents break. This work was commenced in April, 1888.

As for repairing the arch, many plans were suggested. One was to take out the old arch in sections and replace it by a stone arch; another, to take out the old arch as above, replacing it by a concrete one resting upon the old side walls. Neither of these was adopted, but after much delibera-

tion it was decided to excavate above the old arch and back of the old walls and fill in with concrete, removing the old arch after the concrete had set.

In June, 1888, the old shaft was opened, and a heading run both ways along the crown of the arch. This heading was 6 feet by 6 feet, through very heavy earth and heavy timbering: bull pine in pieces of from 10 to 12 inches diameter was used and proved very satisfactory; it was much more economical than hemlock, costing less than one third as much per running foot. The bents were put 3 feet apart, centre to centre, allowing a clear space of 5 feet by 5 feet. Above Fig. 2 is shown the method of timbering these headings. After being run for about fifty feet the heading was then extended down along the line of the arch to a firm foundation back of the side walls, every other bent being knocked out for this purpose and replaced by timbering as shown in Fig. 1. Along the crown of the arch 6-inch scantling were laid on which the sills, 6 inches by 12 inches rested to support the stubs. Concrete was then put into a thickness of from 4 to 4½ feet on the walls and haunches to 3 feet 6 inches on the crown, thoroughly tamped, and the space above, about 3 feet, tightly packed with dry rubble, the stories being about 1½ feet each way. The concrete was mixed in the following proportions, by bulk:

Alsen's German Portland cement	1
Clean sand	2¾
Stone	6¼

The sand was from Perth Amboy and of a high order, consisting almost entirely of quartz with little or no loam; the stone was that taken from the old tunnel, syenitic gneiss and limestone. The concrete set thoroughly in four hours.

It was found expedient after the work had progressed to open a new shaft. The old one was 140 feet deep, and 330 feet west, or 150 ft. from the end, of the tunnel was sunk the new one. From this shaft the headings were run to the ring stones of the tunnel facing. The old shaft was filled with 5 feet of concrete, 14 feet of puddled clay, and the remainder with the material from the tunnel. A Copeland & Bacon (N. Y.) hoisting drum was used.

The concrete invert was put in in 30-ft. sections on Sundays. The wedges above the corbels being driven out, the bents were jacked up and afterwards put down on 6″ × 12″ blocks. The invert was laid to the arc of a circle of 44 feet radius, 21 inches thick at the extremities, 15 inches at the

middle, laid to a form. It was kept clear of water while this work was going on by a Worthington (N. Y. and London) pump; at the same time by levers this water could be thrown up the hill through a 1½ inch pipe to be used in mixing the concrete. This mixing was all done near the shafts, the concrete being taken down for use in the invert on an inclined railway, a car descending pulled up an empty one. For pumping the water from the backing a Blake (N. Y. and Boston) pump was used. Fig. 3 shows the lines of the concrete arch.

While removing the arch, the back of the masonry was so foul that an air drum had to be put in. This was a Sturtevant (Boston) drum which is guaranteed to deliver 10,000 cubic feet of air per minute, running 600 revolutions. The air was carried along by a wooden box 11½ by 36 inches interior dimensions through the tunnel, and back of the masonry by branch boxes 10 inches by 12 inches interior. With a pressure of 85 pounds in the boiler this drum made 560 revolutions. Before it was put in, a number of men had been prostrated while working behind the arch.

After the concrete had been in thirty days, the brick arch and sidewalls were taken out; the 50 feet of stone arching being in excellent condition was not touched. The result is a tunnel with many unique features, and engineers may well be impatient to learn how the concrete arch will hold.

Thanks are due to the officers of the Lehigh Valley Railroad for their courtesy to the writer in giving him free access to the tunnel and to the plans.

THOS. C. J. BAILY, JR.

STANDARD FENCES AND GATES.

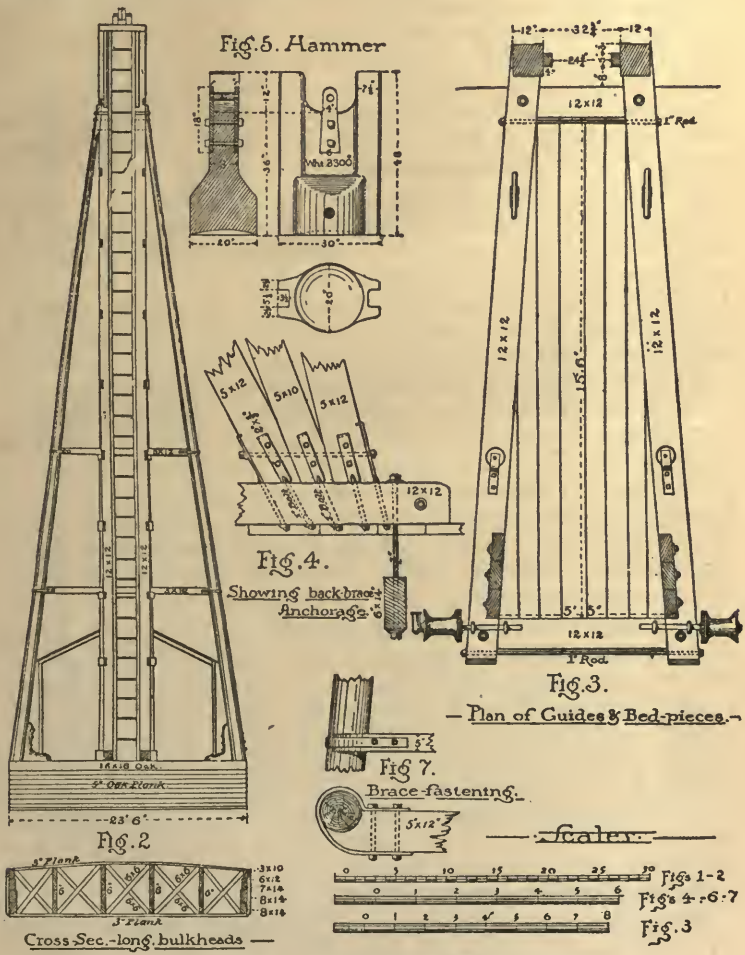
On so long a line as the Canadian Pacific Railway there are all kinds of fences, according to local conditions, and on a very large part of the way no fence at all; but the standard fence and gate, which has been more used than any other, is that of a four-wire fence with a board cap and top board. The two alternate constructions for rock has been quite frequently necessary, there being considerable distances where fence is required, but where there is not soil enough to make it convenient to sink fence posts. The gate is a solid and good one, and proves quite satisfactory when properly put up. All depends, of course on having the posts well set in the ground.

UNDERSTRUCTURE FOR A 40,000-GALLON TANK, CANADIAN PACIFIC RAILWAY.

In the tank the elevation of bottom of sills is 2 ins. above base of rail. The air chamber joists are 4 × 8 ins., the upper and floor joists 3 × 12 ins. ; the sheeting and girting 2 × 4 ins. , the braces and the struts 4 × 6 ins., and the diagonal sills 4 × 12 ins. All the rest of the timber except the 9 × 9 in. diagonal cap is 12 × 12 ins. The sheeting, inside and outside, is $\frac{7}{8}$ in., dressed, seasoned and tongued and grooved. The tie rods are 1 in., with nuts at each end, and 1 in. square drift bolts, 24 ins. long, are used for connections.—P. C. Girouard, in *Engineering News.*

PILE DRIVING MACHINE.

The machine illustrated is one of the very latest in model, and the heaviest in New York harbor.



Details of Pile Driving Machine.

The hull is 56 ft. 6 ins. long and 23 ft. 6 ins. wide over all; each of the sides of the hull is made of four pieces of yellow pine, the two lower each 8 × 14 in., the third 7 × 14 in., the top piece 6 × 14 in., all securely tied by through bolts; the bow planking is oak, 5 ins. thick; the bottom and end plank yellow pine, 3 ins. thick. The bow is further strengthened by a 16 × 16 in. cross timber at top, and at the stern is an 8 × 12-in. cross timber of yellow pine. Oak is used on the bow as being better adapted to stand the constant wear of the piles hauled against it, and to prevent knots or inequalities on the piles interfering with their position under the hammer; the bow planking overhangs 6 ins. in its total height.

The chief end in the design of a hull for a floating pile driver is to obtain longitudinal stiffness, so that the strains between the bow and engine may be properly distributed. To this end our hull is strengthened lengthwise by four wooden bulkheads or kelsons, each 6 ins. thick (Fig. 2) and braced laterally by four sets of X braces of 6 × 6 timber. The hull is further braced in the center by two 3 × 12 in. Y. P. braces, and tie rods or "hog chains" of iron, 1¾ ins. in diameter. Wale pieces and fender plank 3 ins. thick protect the outside of the hull against chafing; the deck has a "crown" of about 6 ins. in its total width.

The hammer-guides are made of two pieces of 12×12 Y. P. 67 feet long from out to out with inside guides of 5×4 in. stuff protected by plate iron ¼ ins. thick; ⅝-in. bolts with countersunk heads fasten the inner guides to the main sticks and at the same time secure the iron work to the same. The bottoms of the main guides are connected with the 12×12 bed pieces, shown in Fig. 3, by two timber knees, and are tied at top by the cap shown in Fig. 6.

The dimensions and general arrangement of the back-bracing is fully shown in Figs. 1 and 3; the bolts used in this portion of the frame work are ⅞ in. diameter. The side braces are round timbers 16-ins. diameter at the butt, and they are anchored to the hull by two heavy timber knees to each. The bed pieces, as shown at Fig. 3, are fastened down to the hull by four bolts each, 1 in. in diameter, the forward bolts passing through the 16×16-in. oak piece on bow, and the after-bolts passing into a cross timber 6×14 ins., as shown at Fig. 4. The foot of the back-bracing is secured to the bed timbers by one 1 in. strap-bolt in each timber, the strap portion of bolt being 2×½ in. in section. A ⅞-in. through-bolt ties the three braces together.

The iron stay-rods running from head of guides to after part of hull are two in number, and are each 1 in. in diameter.

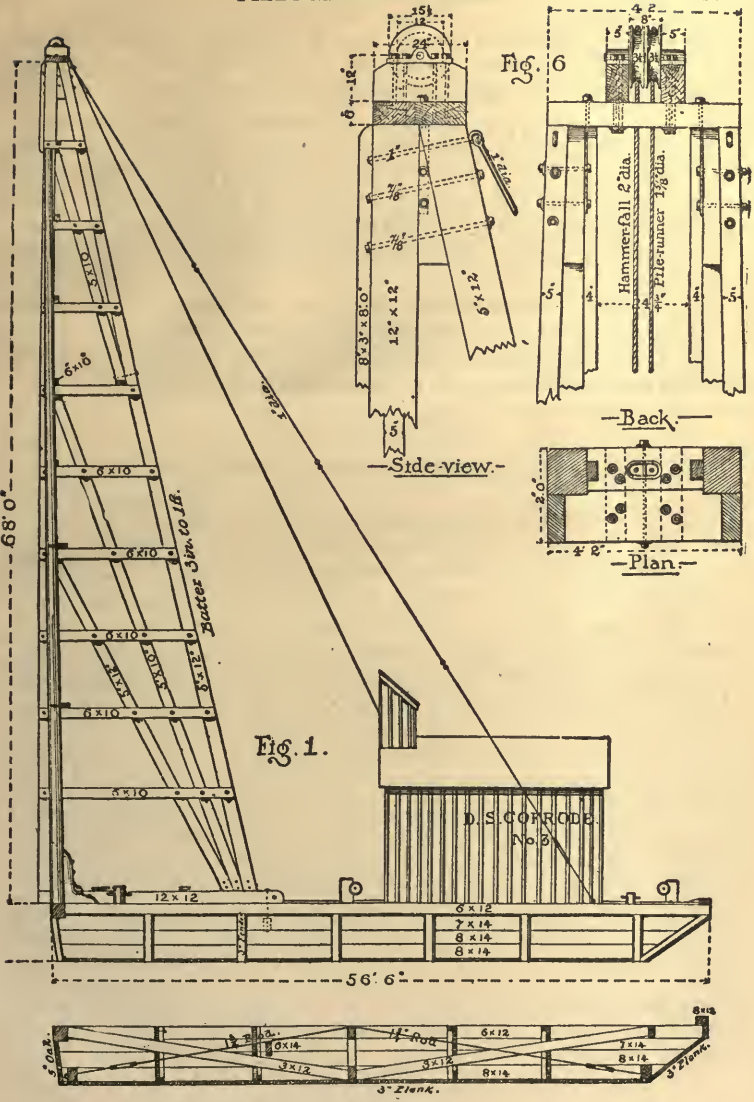


Fig. 6
Hammer-fall 2" dia.
Pile-runner 1⅞" dia.
Back.
Side-view.
Plan.
Fig. 1.
Batter 3 in. to 1 ft.
D. S. COFRODE No. 3
68' 0"
56' 6"
12 x 12
6 x 12
7 x 14
8 x 14
8 x 14
6 x 10
5 x 10
5 x 12
8 x 12
3" Plank.
Long. Sec. showing internal bracing.

The hoisting sheaves on top are two in number, placed side by side. They are 12 ins. in working diameter, 1½ ins. from out to out, and 3½ ins. wide; and the pin passing through them is 2½ ins. diameter at the sheaves, and 2 ins. diameter in the boxes. Experience teaches that these proportions are none too great to stand the severe work frequently put upon it in hoisting heavy weights and tearing out timber. The fall rope attached to the hammer is 2 ins. in diameter, and the "runner" used in hoisting up piles is 1⅝ ins. diameter.

The hoisting engine is a double-drummed Mundy engine of a nominal 25 horse power.

Fig. 5 shows the hammer used with this machine. The drawing is sufficient to show its general design. The weight is 3,300 lbs.

Fig. 7 shows the method of attaching the two 5 × 12 in. horizontal braces to the round side braces, as further shown in Fig. 2.

THE AGE OF RAILROADS IN DIFFERENT COUNTRIES.

England	September 27, 1825
Austria	September 30, 1828
France	October 1, 1828
The United States	December 28, 1829
Belgium	May 3, 1835
Germany	December 7, 1835
Island of Cuba	In the year 1837
Russia	April 4, 1838
Italy	September, 1839
Switzerland	July 15, 1844
Jamaica	November 21, 1845
Spain	October 24, 1848
Canada	May, 1850
Mexico	In the year 1850
Sweden and Peru	In the year 1851
Chili	January, 1852
East Indies	April 18, 1853
Norway	July, 1853
Portugal	In the year 1854
Brazil	April 30, 1854
Victoria	September 14, 1854
Colombia	January 28, 1855
New South Wales	September 25, 1855
Egypt	January, 1856
Middle Australia	April 21, 1856
Natal	June 26, 1860
Turkey	October 4, 1860

RULES FOR MEASURING WORK.

Measure stone work by the cubic foot, plastering by the square yard, brick work by the cubic foot ($20\frac{1}{2}$ brick to the cubic foot); roofing, of slate, tin, gravel or shingles, by the square of 100 feet—thus, $10 \times 10 =$ 100 square feet; flooring the same; roof-painting by the square, same as flooring; for house painting there is no rule. These are the rules generally followed in New York, and their universal use would be advantageous.

DIRECTIONS FOR MAKING DRAWINGS FOR REPRODUCTION.

1. Use a paper with a smooth surface rather than a Whatman or other paper with a rough surface. What is called "ledger" paper, smooth, heavy and white, is well adapted to this purpose.

2. Use very black India ink; the prepared liquid India ink is very good and is always ready.

3. Have your drawing-pen in good condition, so that the lines are sharp and well defined.

4. Use as few shade lines as possible; or if used let them be sharp and well defined, not too close together, and in cylindrical work decreasing in thickness of line as the light is approached.

5. Make the original drawing at least four times the size of the electro-plate wanted. The work is much improved in appearance by being thus reduced, as the lines are finer, and slight errors in drawing are, to a certain extent, decreased in importance.

6. In this reduction remember that all lettering and figures will be reduced in proportion. Consequently in the drawing this lettering and figure work should be, say, twice as high as they are intended to appear on the finished plate, in a drawing to be reduced to one-fourth.

7. Draw the scale on the original so that it may be reduced with it. Unless the reproduced plate is to be of *exactly* the same size, the mere mention of the scale has no value.

8. Avoid all brush shading and color other than dense black.

"A great newspaper, having the confidence of a large constituency, is made in only one way—IT GROWS."

Engineering News

was started as a monthly on April 15, 1874, in Chicago: on January 1, 1876, it was changed to a weekly; on January 4, 1879, it was first issued from its present office in the Tribune Building, New York City. The following figures show its growth in pages and price:

	Reading.	Advertising.	Advertising accounts open, end of each year.	Subscription.
1874..	160	8	4	$2.00
1876..	357	143	34	2.12
1885..	832	832	169	5.00
1891..	1,254	1,872	390	5.00
1892..	1,292	1,920	441	5.00

Concerning our subscription list, our experience has been aptly stated by a contemporary: "There is no forcing process for building up a circulation that can be permanently depended upon. All temporary expedients based on this principle are, sooner or later, apt to react at a loss. The first and paramount thing is to print a steadily progressive and reliable journal of such merit that, being once seen and read, it will create a demand for the next number."

The past volumes of ENGINEERING NEWS constitute an encyclopedia of American public works' construction that has no rival. It has the advantage over the ordinary ponderous reference book which is issued by some publisher once in a decade or two, in that it is always fresh and up to date, and if errors appear, they are promptly criticised and corrected. There is no engineer so thoroughly equipped intellectually and practically that he cannot at times add to his knowledge from the pages of ENGINEERING NEWS; to the young engineer just struggling "for place" in his profession, there can be no agency more helpful than the weekly installment of this journal.

The 19th year and 29th volume of ENGINEERING NEWS *will commence on Jan. 5, 1893. Subscriptions, payable in advance, to United States, Canada and Mexico are: One year, $5.00; six months, $2.50; four months, $2.00. Single copies, 15 cents. To all Foreign Countries in the Postal Union add 4 cents per copy to above prices for postage. No club rates. No commission to agents. Bound volumes: Six months, $4.00; twelve months, $6.75.*

ENGINEERING NEWS *is the best medium for advertisers who wish to reach the engineering profession in all its branches, civil and military; contractors for public works; and railroad officials interested in the construction and maintenance of track. These are its special departments, in which it has no superior in America.*

Address all correspondence to

ENGINEERING NEWS PUBLISHING CO.,

TRIBUNE BUILDING, NEW YORK CITY.

APPENDIX.

BOOKS FOR RAILROAD ENGINEERS.

The studies of a young railroad engineer, who has not had the advantages of a technical education, naturally lie in the same direction as those pursued by students in engineering schools. In general, it may be said that a list of books used in such schools would be an advantageous one for the young railroad engineer to follow, but such lists can be obtained by applying for catalogues of the institutions themselves. We will not, therefore, here attempt to give an outline of such formal courses of study, although some of the books will be mentioned under the separate headings below.

MATHEMATICS.

There are so many excellent series of mathematical text-books, that a selection of any single one would be a difficult matter, and might almost seem invidious. The works of Simon Newcomb, professor in the United States Naval Observatory and in Johns Hopkins University, are extensively used in the technical schools, and take a deservedly high rank. Among others may be mentioned the books of Professor Bowser, of Rutgers College, and those of the late Professor Olney, of the University of Michigan. It should be said that in these and many other series there are elementary, collegiate and also advanced works. It would probably be best for the railroad engineer to purchase an advanced algebra or calculus, rather than an elementary or an intermediate one; for the first certainly contains all that the others do, and besides has the advantage of covering the ground in a manner more complete, so that it may serve for a reference book. In higher mathematics, the field engineer will rarely have the time or opportunity to read many works, but Muir's Determinants, Hardy's Quaternions and Baker's Elliptic Functions may be noted as books introducing to the higher analysis. Ball's Short Account of the History of Mathematics (12mo, 464 pages), is an interesting work for all with mathematical tendencies. The thorough treatise of Carll on Cal-

culus of Variations (8vo, $5), has special interest from the fact that its author is blind. The best mathematical cyclopedia is Carr's Synopsis of Results in Pure Mathematics (London, 1886, large 8vo, 935 pages, $13.50).

SURVEYING.

The standard works on railroad surveying are generaly known to the young railroad engineer. Among these Searles' Field Engineering (fifteenth edition, pocket form, $3), is usually considered to be one of the best, both in theoretical and practical lines, and its tables are certainly most excellent for ready use in the field. The field book of Shunk, and that of Henck, have also been extensively used, and Searles has a separate small work on The Railroad Spiral. In the survey of public lands, the best work is the Manual of Surveying, by F. Hodgman (fifth edition, with tables, $2.50). As a general work, however, Johnson's Theory and Practice of Surveying (ninth edition, 754 pages, 150 cuts, with folding maps and tables, $4) may be said to cover in an excellent manner the subjects of land, city, topographic and geodetic surveying. Special books on the last mentioned branch will be noted below under Astronomy.

TABLES.

The best six-place logarithmic tables with which we are acquainted are those in Searles' Field Engineering, mentioned above. It is, however, a matter of regret that five-place tables have not been given in field books, since they are far more convenient and are sufficiently accurate for problems in railroad surveying. Ludlow's Tables (8vo, $2), is an excellent set of five-place logarithms for office use, which compare favorably with the German ones of Gauss and Schoen. Among seven-place tables those of Vega and Schroen are counted among the best, the former having old style type and the latter modern type. In geodetic work eight-place logarithms are sometimes needed, and for this purpose Vega's Thesaurus Logarithmorum, giving ten-place tables should be used; a photolithographic reproduction of this, with all errors corrected, has lately been published at a low price.

MECHANICS.

The subject of mechanics includes the fundamental principles which underlie all field construction, and particularly the design of arches, bridges, trestles and machinery. It is properly regarded as one of the most important studies in engineering schools. Wood's Principles of

Elementary Mechanics (now in its ninth edition, 12mo, $1.25) is a standard book, which sets forth the fundamental principles in a clear and simple manner. An advanced work by the same author is the Elements of Analytical Mechanics (seventh edition, about 500 pages, octavo, $3), and there are also many excellent books by other American authors. Merriman's Mechanics of Materials (fourth edition, octavo, interleaved, $3.50) treats of the strength of materials and the theory of beams, columns and shafts. Among other works Lanza's Applied Mechanics (fifth edition, 929 pages, $7.50) and Church's Mechanics of Engineering (834 pages, octavo, $6), may be noted as well known, both in technical schools and as books of reference by engineers. The special practical applications of mechanics are found in books noted below under the headings of Roofs and Bridges, Construction and Hydraulics.

ARCHITECTURE.

Kidder's Architects' and Builders' Pocket-Book (tenth edition, 883 pages, with over 400 illustrations) is a standard work in the architectural profession, occupying indeed the same place that Trautwine's does to the Civil Engineer. Birkmire's Architectural Iron and Steel (second edition, 201 pages, $3.50), gives the most recent details concerning the use of iron and steel in architectural engineering. Merrill's Stones for Building and Decoration (a recent work, octavo, 453 pages, $5) gives an excellent general outline of the physical and chemical properties of building stones, together with a description of quarry methods, stone working machines and the weathering and preservation of building stones. Berg's Buildings and Structures for American Railroads (quarto, 500 pages, 691 figures, $7.50) is an exhaustive practical work which every division or resident engineer should have on his desk.

ASTRONOMY AND GEODESY.

Few astronomical problems are required in the practice of a railroad engineer. The introduction of electric railways, however, which are often to be built in straight lines between distant points, requires the determination of azimuth. The elementary methods for this purpose are given in books of surveying, but when distance between points becomes considerable, as, for example, in the electric line between Chicago and St. Louis, extended computations are required which involve the methods of geodesy. Johnson's Surveying gives full details regarding these problems, and a more special book for the

observer is Doolittle's Treatise on Practical Astronomy (third edition, 642 pages, $4), which is well known as a standard among geodesists. The computation of geodetic latitudes and longitudes will often be found necessary in this connection. These are set forth in fullest detail in the papers of the United States Coast and Geodetic Survey, but they may also be seen in Merriman's Geodetic Surveying (1892, octavo, 170 pages, $2). For the adjustment of precise observations Merriman's Method of Least Squares (sixth edition, 198 pages, octavo, $2) may be quoted as a well known standard text-book. Wright's Adjustment of Observations (octavo, 437 pages, $4) is a thorough work for special geodetic triangulations.

BRIDGES AND ROOFS.

The computation of stresses is, of course, the first part in the investigation or design of a bridge or roof truss. The first treatment of this subject was given in 1847 by Squire Whipple, and, twenty-five years ago, his book and one by Herman Haupt (revised edition, 1871; 268 pages, with 16 plates, $3.50) were the only ones by American authors. To-day, however, there are a large number from which a choice can be made. Du Bois' Strains in Framed Structures (eighth edition, over 500 pages, quarto, $10) is one of the most comprehensive, including not only computation of stresses, but the discussion and designing of details, and the preparation of working drawings. Greene's Roof Trusses and Merriman & Jacoby's Graphic Statics, give methods of determining stresses on the drawing board which will be found especially advantageous for roofs. Burr's Stresses in Bridge and Roof Trusses (475 pages, octavo, with 13 plates, $3.50) is a valuable contribution to the subject, and the seventh edition contains an appendix on cantilevers. Foster's Wooden Trestle Bridges (quarto, 150 pages, 38 plates, 150 cuts, $5) is a practical book, showing trestles of all kinds, which also treats of methods of erection, protection against accidents, and gives numerous standard specifications. We find announced as in preparation a work on Framed Structures by Johnson, Bryan & Turneaure, and also a volume on Bridge Design by Professor Merriman, which will form Part III. of his Text-Book on Roofs and Bridges (Part I., Stresses, $2.50; Part II., Graphic Statics, $2.50).

CONSTRUCTION AND OPERATION.

Baker's Masonry Construction (sixth edition, 556 pages, octavo, $5) takes high rank as a valuable theoretical and practical book, treating

not only of stone work, but also of the important subject of foundations. Berg's Buildings and Structures for American Railroads (500 pages, 691 cuts, quarto, $7.50) is a work just published, which must necessarily be in the library of every railroad designing engineer, including as it does the details of the construction of buildings of all kinds from watchmen's shanties to large terminal passenger stations. Byrne's Highway Construction (686 pages, octavo, $5), Meyer's Modern Locomotive Construction (658 pages, 1,030 cuts, $10), Thurston's Materials of Construction (765 pages, octavo, 177 cuts, $5), Hering's Recent Progress in Electric Railways (12mo, 389 pages, 104 cuts), Martin & Wetzler's Electric Motor and Its Application (quarto, 315 pages, 353 cuts), and American Practice in Block Signaling (72 pages, small quarto, $2), may be mentioned as recent authoritative books in the several departments of which they treat. Wellington's Economic Theory of the Location of Railways (fifth edition, 980 pages, 313 cuts, octavo, $5) brings together a great mass of matter relating to construction and operation of railroads, as well as to location, the whole discussion being with reference to the most judicious expenditure of capital. Drinker's Tunneling, Explosive Compounds and Rock Drills (third edition, 1,143 pages, 19 plates, quarto, $25) is a most valuable historical and descriptive practical book. Wegmann's Masonry Dams, Merriman's Retaining Walls, Carpenter's Manual of Experimental Engineering, Thurston's Manual of the Steam Engine, Peabody's Thermodynamics, Wilson's Steam Boilers, Wood's Compound Locomotives, Forney's Catechism of the Locomotive, Parson's Track, Clark's Building Superintendence, and Ihlseng's Manual of Mining are other books which may be considered as safe, reliable and standard in their special field. Of course, the Pocket-Book of Trautwine is well known as the basis of every library, and the one book which a railroad engineer must have; now in its forty-first thousand, it stands as a monument of patient industry on the part of its authors.

HYDRAULICS.

A general acquaintance with the principles of hydraulics is absolutely essential for the successful design of culverts, piers and other structures in water. Fundamental principles are given in Merriman's Treatise on Hydraulics (fourth edition, octavo, 384 pages, 109 cuts, many tables, $3.50), which is designed as a text-book for technical schools, and also for use of engineers. Smith's Hydraulics (quarto, 362 pages, 16 plates, $8) is an elaborate work, giving discussions of the

coefficients derived from many experiments. Nichols' Water Supply (8vo, 232 pages, 54 cuts, $2.50) contains accounts of the methods of ascertaining and securing the purity of water, which is a very important matter in planning water supplies for stations and other railroad buildings. Fanning's Water Supply Engineering, Staley & Pierson's Separate System of Sewerage, and Baumeister's Cleaning and Sewerage of Cities may be noted as standard works, covering a wide field in the important subjects of public water supply and sanitation. The Manual of American Water Works, published by Engineering News Publishing Company, New York, is a comprehensive cyclopedia of statistics and historical information concerning public water supplies.

WORKS OF

Professor Mansfield Merriman.

A TREATISE ON HYDRAULICS.
Fourth edition, revised, 8vo, cloth.....$3.50

A TEXT-BOOK ON THE METHOD OF LEAST SQUARES.
Sixth revised edition, 8vo, cloth.....$2.00

THE MECHANICS OF MATERIALS, AND OF BEAMS, COLUMNS AND SHAFTS.
Fourth edition, 8vo, cloth.....$3.50

A TEXT-BOOK ON ROOFS AND BRIDGES.
PART I. STRESSES IN SIMPLE TRUSSES. Third edition, 8vo, cloth.....$2.50
PART II. GRAPHIC STATICS. Third edition, 8vo, cloth.....$2.50
PART III. BRIDGE DESIGN. (In preparation).

RETAINING WALLS AND MASONRY DAMS.
1892, 8vo, cloth.....$2.00

INTRODUCTION TO GEODETIC SURVEYING.
Including Figure of the Earth, Method of Least Squares and Field Work of Triangulation. 8vo, cloth.....$2.00

—FOR SALE BY—

ENGINEERING NEWS PUBLISHING CO.,
TRIBUNE BUILDING,
NEW YORK.

Verrick
Engine

UCSB LIBRARY
X-62985

UC SOUTHERN REGIONAL LIBRARY FACILITY
A 000 631 266 4

ENGINEERING NEWS

AND

AMERICAN RAILWAY JOURNAL.

PUBLISHED WEEKLY BY

ENGINEERING NEWS PUBLISHING CO.

TRIBUNE BUILDING, NEW YORK.

SIXTY PAGES.

SUBSCRIPTION PRICE: $5 PER ANNUM. $2 FOR FOUR MONTHS.

To Chief Engineers of Railroads.

If you want to make up a Survey Party!

If you want an Engineer on Construction!

If you want to fill a vacancy in Maintenance of Way Department!

If you want an Engineer for Special Service!

If you want a Draughtsman!

If you want a Contractor!

Advertise in the "Wants" columns of ENGINEERING NEWS, and save Time, Trouble and Expense. There is but one best method of doing anything, and this is the "Best Method" of accomplishing the above.

Copy for "Want" advertisements will be received as late as 10 A. M. Wednesday in time for publication in current issue.